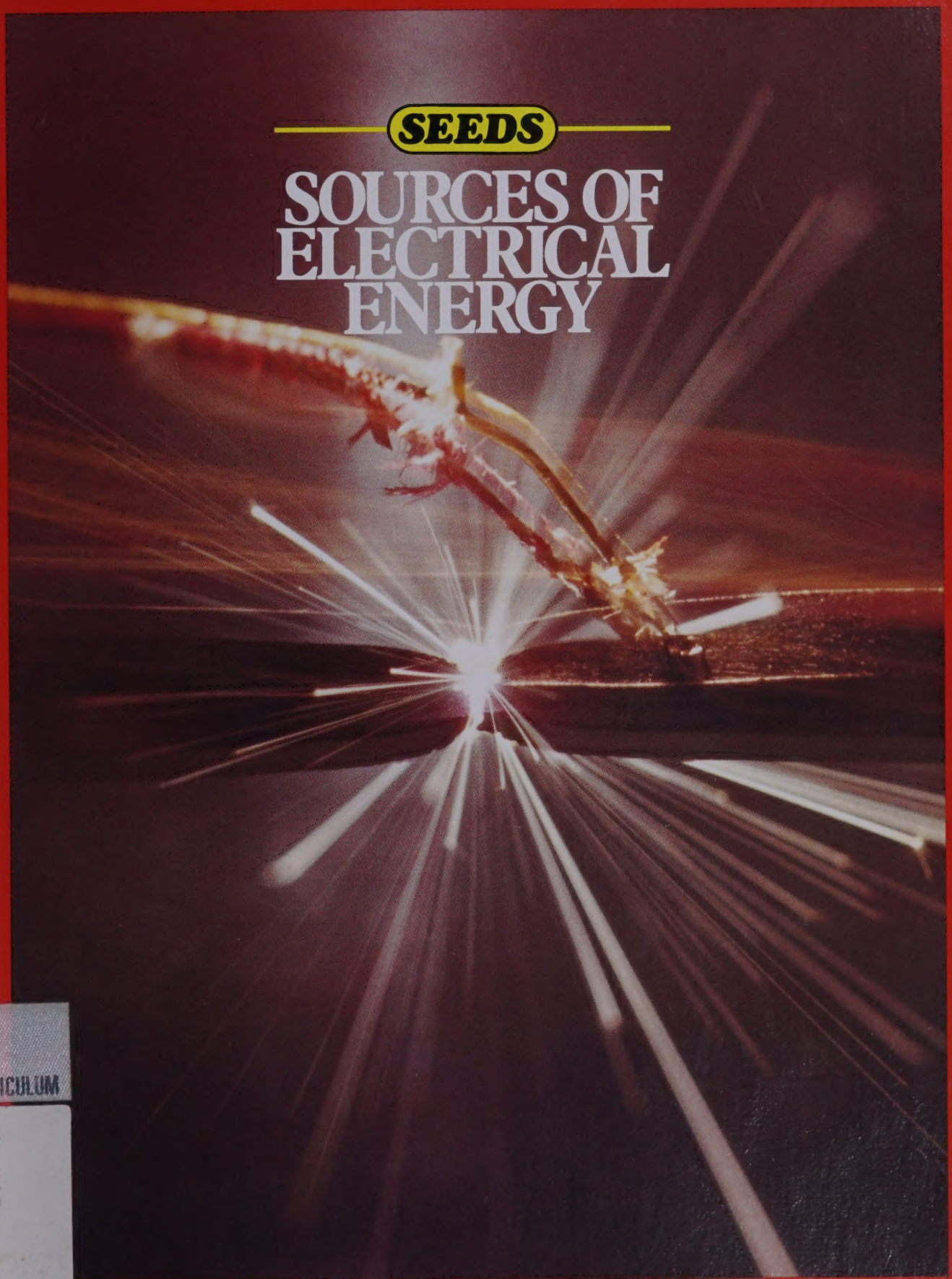
SEEDS

# SOURCES OF ELECTRICAL ENERGY



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**SEEDS**

**The Energy Literacy Series**

# SOURCES OF ELECTRICAL ENERGY

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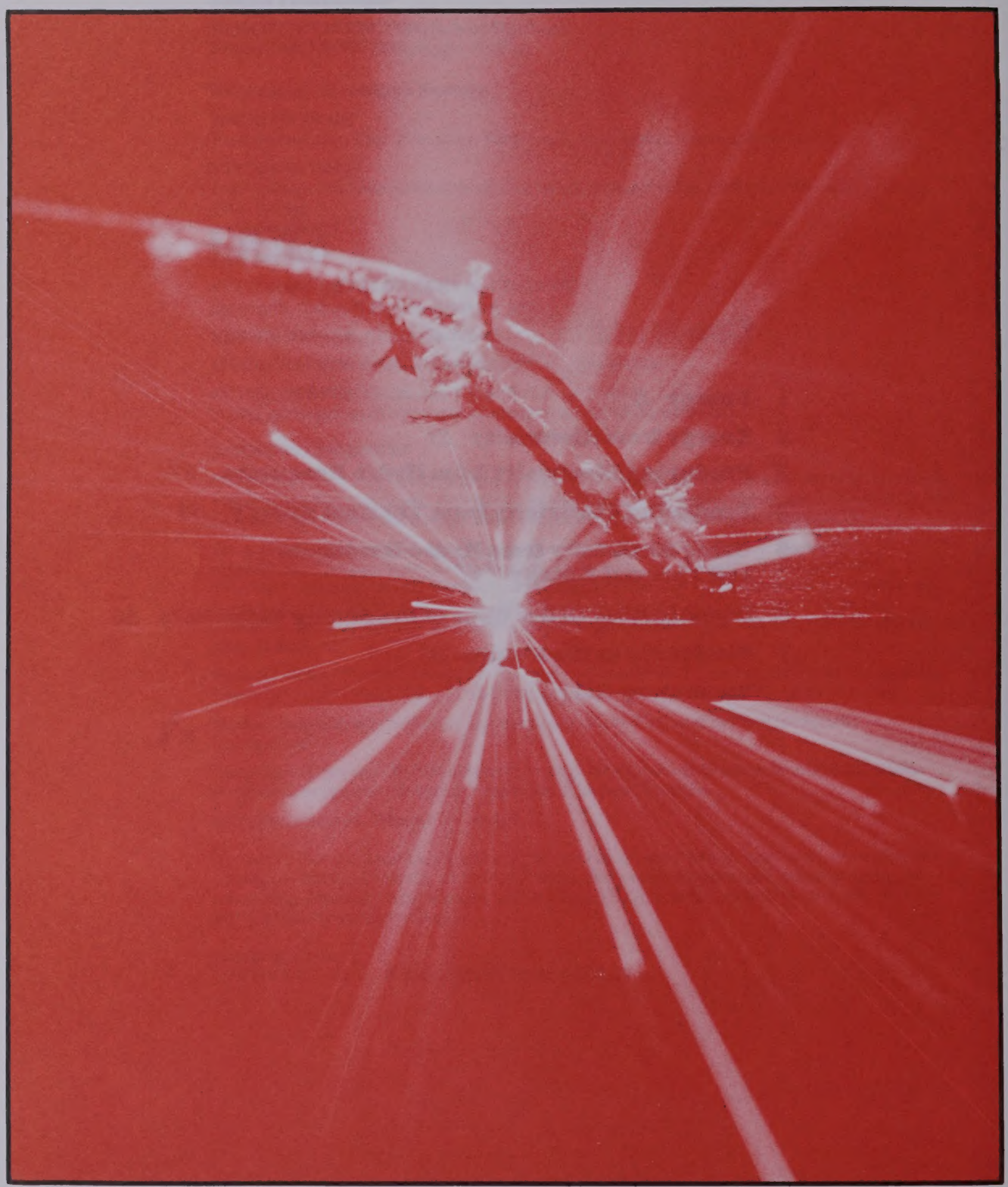
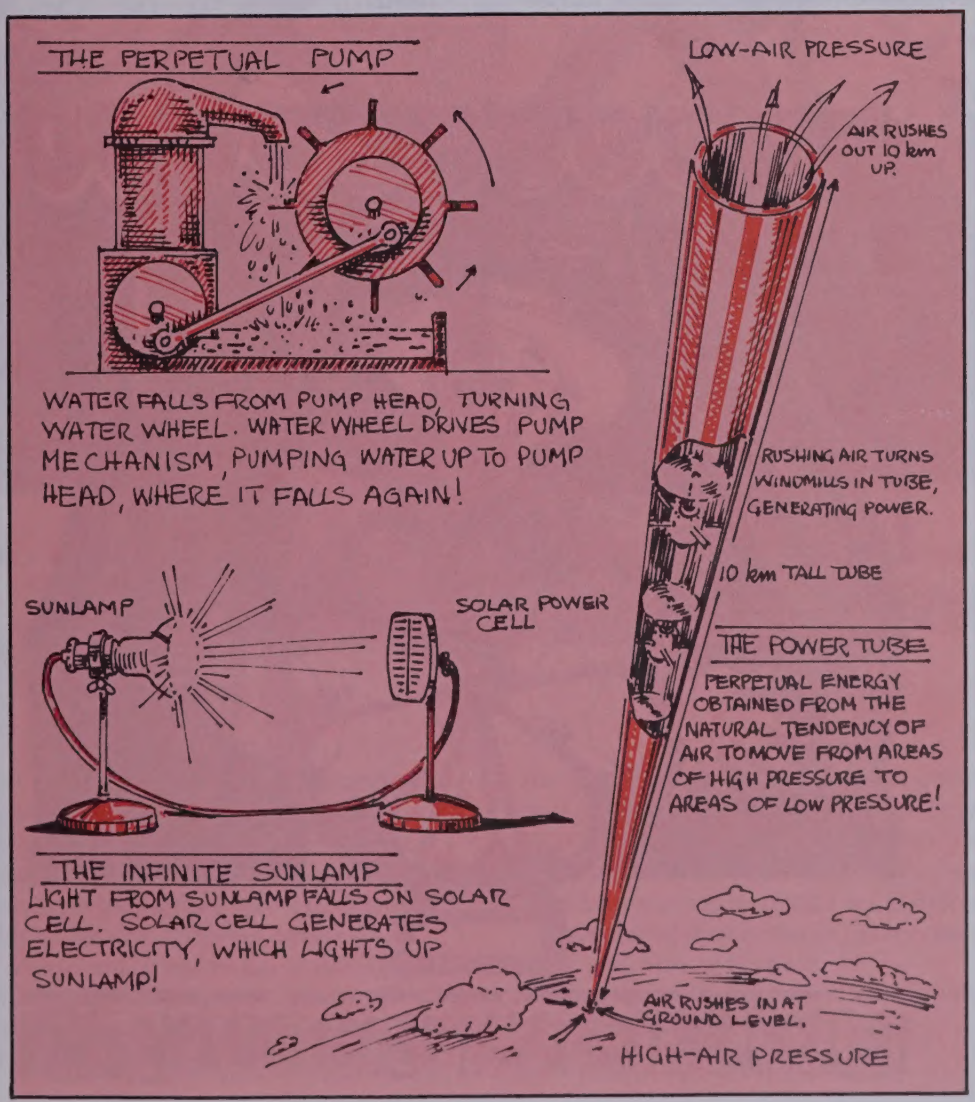


# 1
# Energy

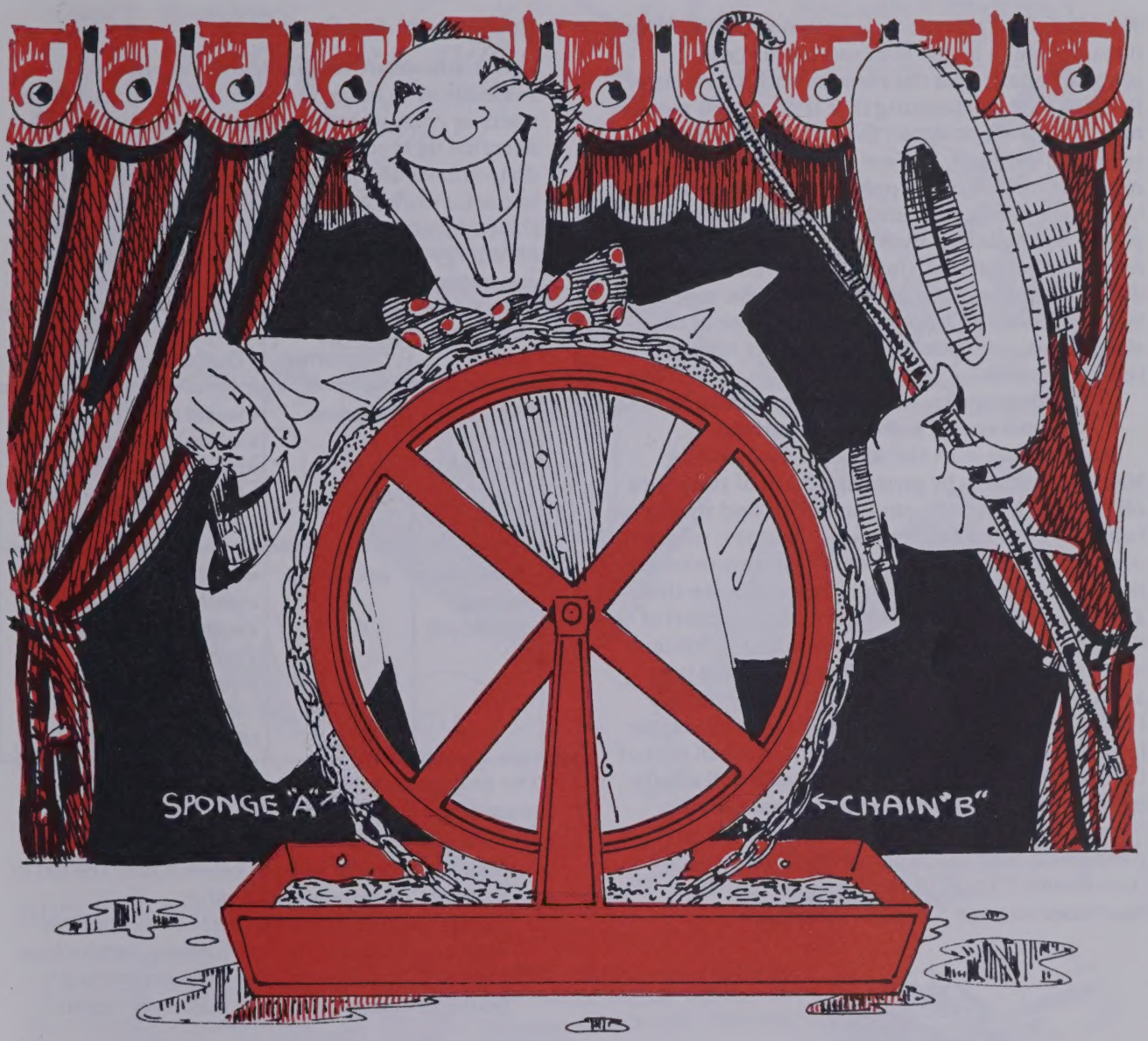
**Perpetual-Motion Machines—Energy Forever?**


THE PERPETUAL PUMP
WATER FALLS FROM PUMP HEAD, TURNING WATER WHEEL. WATER WHEEL DRIVES PUMP MECHANISM, PUMPING WATER UP TO PUMP HEAD, WHERE IT FALLS AGAIN!
SUNLAMP
SOLAR POWER CELL
THE INFINITE SUNLAMP
LIGHT FROM SUNLAMP FALLS ON SOLAR CELL. SOLAR CELL GENERATES ELECTRICITY, WHICH LIGHTS UP SUNLAMP!
LOW-AIR PRESSURE
AIR RUSHES OUT 10 km UP.
RUSHING AIR TURNS WINDMILLS IN TUBE, GENERATING POWER.
10 km TALL TUBE
THE POWER TUBE
PERPETUAL ENERGY OBTAINED FROM THE NATURAL TENDENCY OF AIR TO MOVE FROM AREAS OF HIGH PRESSURE TO AREAS OF LOW PRESSURE!
AIR RUSHES IN AT GROUND LEVEL.
HIGH-AIR PRESSURE

# Step Right Up...

*ladies and gentlemen, and see the wonder of this century: the perpetual-motion machine! That's right, ladies and gentlemen, perpetual motion. You can start one of these machines turning and it spins forever. Look closely. You will notice there is no fuel tank. That's right, no fuel tank. What a blessing in these days of fuel shortages. So what makes it go? What is the secret source of energy for this wonderful invention? The answer, ladies and gentlemen, is gravity. That's right, gravity. We may run out of coal and gasoline, but we're never going to run out of gravity.*

*This is how the wheel works. Just give it a little push to get it turning. The metal balls start rolling. They add a turning force to the wheel. Once the wheel is turning, nature keeps it going forever. Attach any machine you like to the other end, from an egg beater to a generator. What's that you say, sir? A generator needs a lot of energy to turn it? An easy matter, sir. Just build a big wheel and use lots of heavy weights. Once you have bought one of these amazing machines, ladies and gentlemen, your imagination is the only limit for ways it can be used.*




*For those of you who like a choice, I am happy to say that we have a second perpetual-motion machine here today. As before, you will see no fuel tank, because this machine, ladies and gentlemen, does not run on fuel. No, it runs on the Great Principles of Nature. Observe carefully.*

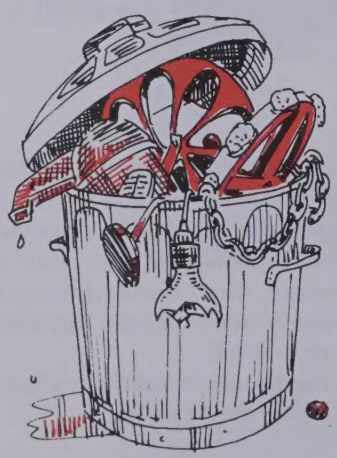
*The sponge at A is dry. It soaks up water and becomes heavy enough to move the sponges around the frame so the next dry sponge can soak up water. As the sponges move, they have the water squeezed from them by the chain, B. As you can see, ladies and gentlemen, the energy that drives this wonderful machine comes from nature! It's natural for a sponge to soak up water and become heavy. And I must also say that it is only natural that a clever person like me would try to put nature to work.*

*These perpetual-motion machines are now on sale. The line forms to the right.*

Would you buy a perpetual-motion machine? Even if you refuse to invest your money, you will probably admit that the ideas sound convincing. Perhaps you are thinking that if perpetual-motion machines were possible, they would have been perfected long ago. You are right. The creation of a machine that would supply its own energy was an inventor's dream for hundreds of years. Clever people devoted their lives and their fortunes to the dream, but all of them failed. What the inventors did not know is that a perpetual-motion machine is not possible. It is not possible because of one simple idea about energy that was not known then. Here it is:

> When energy is converted to another form, some energy is always lost as heat.

Suppose you start the wheel of the "Gravity Machine" moving by giving it a push of 100 units of energy. The wheel spins smoothly and the metal balls start rolling in their cages. Now you measure the output energy at the axle. It will always be less than 100 units. The friction (the resistance that always occurs when two objects rub together) of the axle rubbing on its bearings, and the friction of the weights rolling in their cages, create heat and use up a tiny part of the 100 energy units. Lubricating oil and good bearings will reduce the friction, but will never eliminate it. A small part of the 100 units of energy from the push will always be used up in heat, and the perpetual-motion "Gravity Machine" will always come to a stop. Can you explain why the "Sponge Machine" will not turn forever? Try to explain why each of the machines on page 5 will not run forever.



## Consumers Are Converters

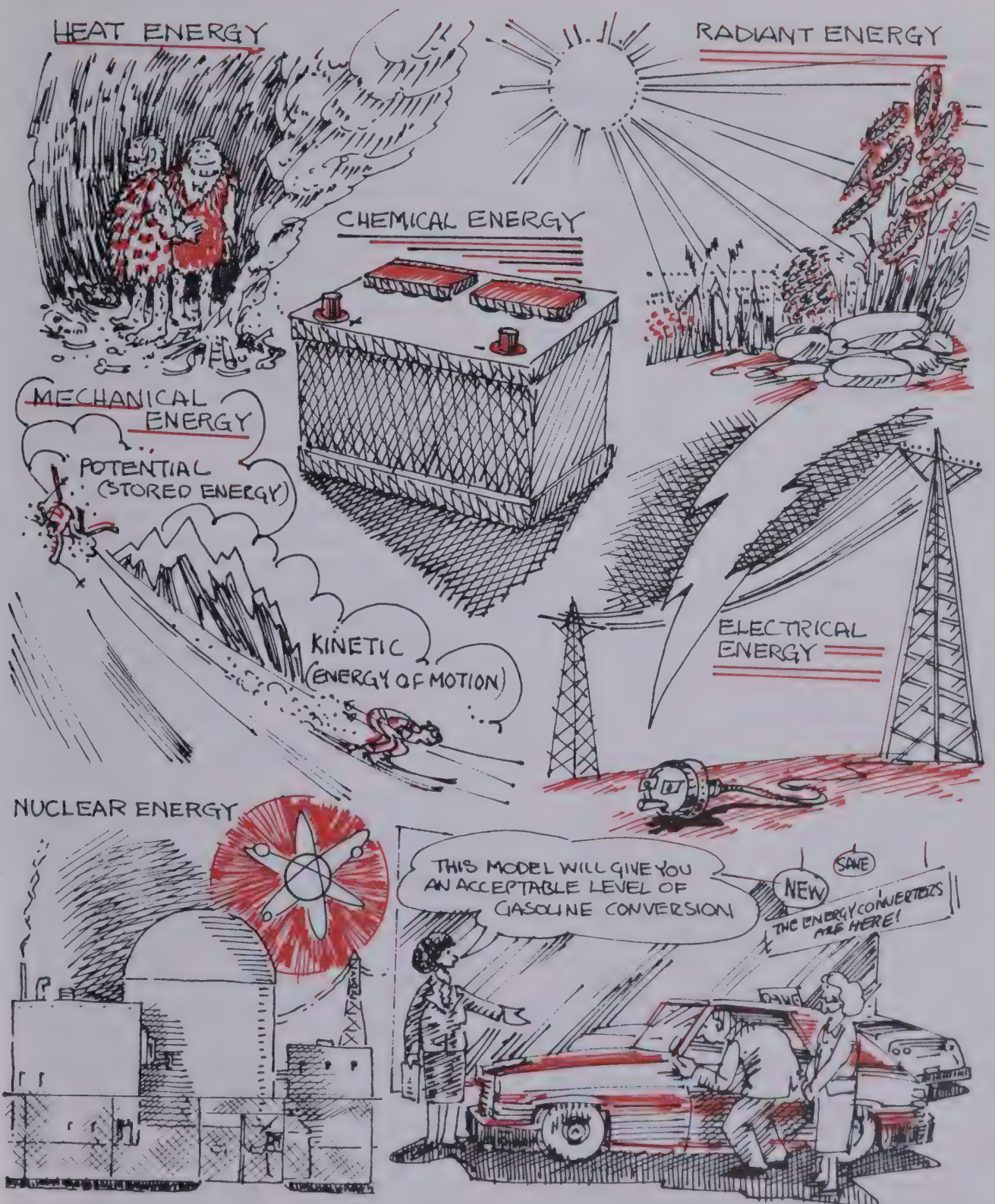
In Canada we are fortunate to have energy available in so many forms. All of us can be called users or consumers of energy. A better word to describe us is converters, because that is what we do to almost all forms of energy—we convert them to useful work. When we do this, we lose some of the energy to waste heat. The waste heat is a kind of "energy tax" we have to pay every time energy is converted from one form to another.

| Energy Input | Energy Converter | Energy Output |
|---|---|---|
| chemical energy (jet fuel) | jet plane | • waste noise energy<br>• waste heat energy<br>• useful mechanical—kinetic—energy (plane flies) |
| chemical energy (firewood) | woodstove | • waste heat energy<br>• waste noise energy<br>• waste chemical energy (smoke)<br>• waste light energy (not seen inside stove)<br>• useful heat energy |

*The energy input in the table is the energy source, the energy converter is the user of the energy, the energy output is what results.*

1. Make a table like the one below. Enter the list of Energy Converters in the table.
2. Complete the Input and Output columns for each energy converter: oil furnace, school bus, lightbulb, sunflower, coal-fired generating plant, hydroelectric plant, bulldozer, robin.

| ENERGY INPUT | ENERGY CONVERTER | ENERGY OUTPUT |
|---|---|---|
| | OIL FURNACE | |
| | SCHOOL BUS | |
| | | |
| | | |


HEAT ENERGY
RADIANT ENERGY
CHEMICAL ENERGY
MECHANICAL ENERGY
POTENTIAL (STORED ENERGY)
KINETIC (ENERGY OF MOTION)
ELECTRICAL ENERGY
NUCLEAR ENERGY
THIS MODEL WILL GIVE YOU AN ACCEPTABLE LEVEL OF GASOLINE CONVERSION
NEW
SAVE
THE ENERGY CONVERTERS ARE HERE!
DAVE

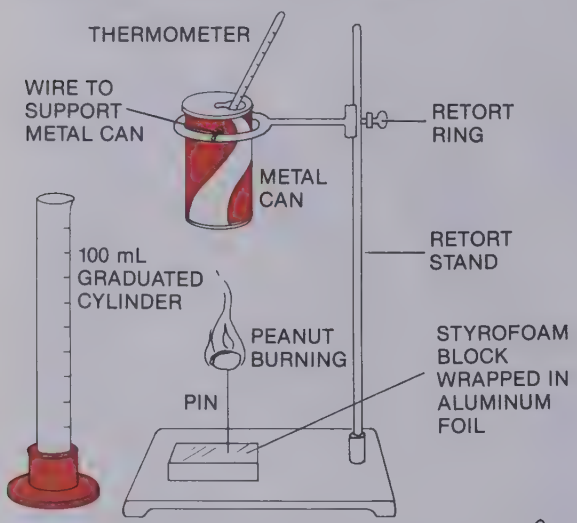
## Energy Units

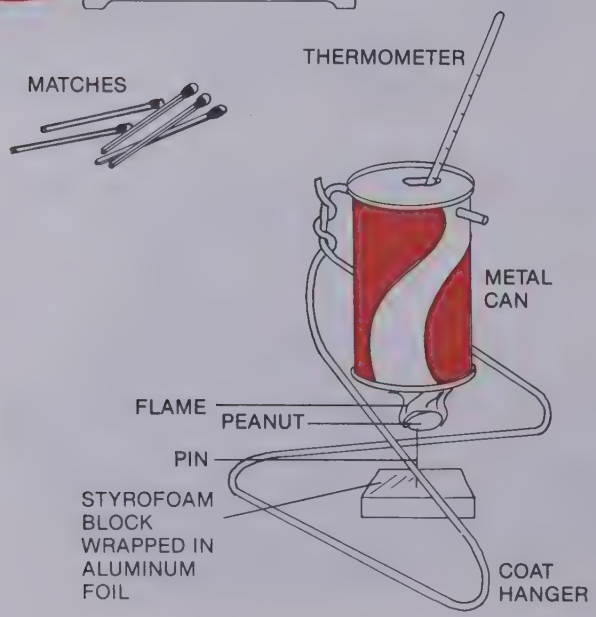
### Activity

### How Much Heat Energy Is There in a Peanut?

You can calculate the approximate heat energy in a peanut by doing the following activity.

**MATERIALS** You will need a small can, such as a soup can, a peanut, cold water, 5 wooden matches, a thermometer, a 100-mL graduated cylinder, 15 cm of coat-hanger wire or a retort stand, a retort ring, a 2 cm × 8 cm × 8 cm small Styrofoam block, some aluminum foil, and a straight pin of about 5 cm in length.




**PROCEDURE** Wrap the Styrofoam in aluminum foil with the shiny side out, to protect the Styrofoam from the heat.

Push the pin through the center of the Styrofoam.

Attach a shelled peanut to the pin by pressing it onto the point of the pin.

If you do not have a retort stand, bend a coat hanger to make a stand for the can as shown.

Measure 100 mL of cold tap water in the graduated cylinder and pour it into the can. Measure the temperature of the water and record it.

Place the can in the coat-hanger stand. Place the Styrofoam pad and the peanut below the tin can. The bottom of the tin can should be 3 cm above the top of the peanut. Raise the styrofoam on a firm support, if necessary.

Light the peanut with a wooden match. Be prepared to re-light the peanut *immediately* if the flame goes out before all of the peanut has burned.

When the peanut stops burning, stir the water, and then measure and record the temperature of the water. *Be careful not to touch the bottom of the can, as it is hot and the black carbon will rub off very easily.*

**OBSERVATION**

Temperature of water after heating = ____ °C.

Temperature of water before heating = ____ °C.

Temperature change = _____ Celsius degrees.

**CONCLUSION** Calculate how many joules of heat energy a burning peanut releases by multiplying the temperature change by 420. Since food energy is measured in kilojoules (kJ), divide your answer by 1000 to obtain your answer in kilojoules.

**EXTENDED CONCLUSIONS** Now that you have found the number of kilojoules of food energy in a peanut, apply this data to the following problems.

1. To walk 1 km requires 220 kJ of energy. How many peanuts would you have to eat to supply this amount of energy?
2. Only 50 kJ are needed to cycle 1 km. How many peanuts would supply 50 kJ of energy?
3. A midsize car uses 5000 kJ in travelling 1 km. How many peanuts are required to make the equivalent of 5000 kJ?

Energy is measured in joules. Holding a flashlight battery in one hand and raising it one metre uses about one joule (1 J) of energy. To say that another way, one joule of chemical energy stored in you is converted into useful energy, plus some heat, when you raise a flashlight battery one metre.

A joule is a very small unit of measurement. Larger units are often needed to measure energy.

1 000 J = 1 kJ (kilojoule)
1 000 000 J = 1 MJ (megajoule)

## Energy Input

The energy we get from food is measured in joules. You will also see ratings of food in Calories. To change Calories to joules, use this:

1 Calorie = 4.2 kJ

1. Calculate your energy input for three meals and snacks on a typical day.
2. Make a table of your energy input.

| BREAK-FAST ITEMS | FOOD ENERGY kJ | LUNCH ITEMS | FOOD ENERGY kJ | SUPPER ITEMS | FOOD ENERGY kJ |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| TOTAL | kJ | TOTAL | kJ | TOTAL | kJ |

TOTAL FOR THE DAY _____ kJ

## Energy in Food: Individual Portions (kilojoules)

| | | | | | |
|---|---|---|---|---|---|
| Apple | 300 | Cucumber | 20 | Pancakes (1) butter, syrup | 1300 |
| Apple juice | 250 | Custard | 600 | Peach, fresh | 150 |
| Bacon, 4 slices | 1030 | Danish pastry | 1155 | Peanuts | 880 |
| Banana | 420 | Doughnut | 525 | Peas | 240 |
| Beans — baked | 650 | Eclair | 1325 | Pie | 1680 |
| — green | 65 | Egg — boiled, poached | 335 | Pizza | 1320 |
| Beef — ground | 1000 | — scrambled, fried | 465 | Plum, fresh | 105 |
| — rib roast | 1575 | Eggroll | 1000 | Popcorn | 630 |
| — sirloin steak | 1385 | Fish, fried | 625 | Popsicle | 295 |
| Beef stew | 880 | French fries | 650 | Pork — chop | 1090 |
| Beets | 120 | Grapefruit | 190 | — roast | 1300 |
| Bread, 1 slice | 345 | Grapes | 135 | Potato (1) | 355 |
| Butter | 150 | Ham | 1030 | — chips | 965 |
| Cabbage roll | 1100 | Ice cream — plain | 200 | Raisins | 335 |
| Cake with icing | 1680 | — sundae | 2390 | Rice | 400 |
| Candy bar | 540 | Jam and jelly | 460 | Sausage | 790 |
| Carrots | 90 | Lamb — chop | 1680 | Soft drinks | 500 |
| Cauliflower | 100 | — roast | 990 | Soup | 420 |
| Celery | 20 | Lasagna with meat | 2260 | Spaghetti, meat sauce | 1385 |
| Cereals — dry | 460 | Lettuce | 40 | Spinach | 85 |
| — cooked | 540 | Lentils | 335 | Squash | 275 |
| Cheeseburger | 1900 | Liver — beef | 545 | Sugar | 170 |
| Cheese — cheddar | 490 | — chicken | 620 | Tea, cream and sugar | 360 |
| — cottage | 500 | Lunch meat | 350 | Tomato juice | 140 |
| Chelsea bun | 665 | Macaroni and cheese | 1800 | Turnip | 145 |
| Coffee, cream and sugar | 360 | Mayonnaise | 420 | Waffles (1) butter, syrup | 1680 |
| Corn | 290 | Milk — whole | 670 | Wiener (1) | 710 |
| Crackers, 4 | 200 | — 2 % | 515 | Yogurt, plain | 470 |
| Cream | 125 | — skim | 380 | | |
| Chicken | 485 | Milkshake | 1175 | | |
| Cookies — plain | 85 | Orange | 270 | | |
| — filled | 335 | Orange juice | 230 | | |

## Energy Output—Work and Play

During the day you take in energy every time you eat. You also use up energy with every activity, sitting still, or sleeping. The amount of energy needed for each of the day's activities varies a little with each individual according to height and mass and other factors.

| | kJ/h |
|---|---|
| Sleeping | 260 |
| Sitting quietly | 420 |
| Sitting but working | 630 |
| Standing, light work | 630 |
| Sitting, heavy work | 760 |
| Sitting, light work with walking | 740 |
| Walking, some lifting and pushing | 1270 |
| Heavy work | 1850 |
| Heaviest work | 2320 |

*The figures in this table are averages.*

1. How much energy did you use up today? List all of your activities, beginning at midnight and ending at midnight the following day.
2. Activities that take less than an hour can be shown as fractions of an hour. Which was greater for the day, your energy input or your energy output?

The human body is capable of storing energy. When you take in more energy than you use up, the extra energy is stored in the form of body fat. There are three logical ways to control the amount of fat we carry. One is to keep activities at the same level, but lower the energy intake. We do this when we give up some of the high-energy, low-nutrition "fun foods." What are the other ways to control body fat?

| kJ/h | | kJ/30 min | | kJ/10 min | |
|---|---|---|---|---|---|
| horseback riding (trot) | 2000 | tennis | 880 | swimming | 300 |
| cross-country skiing | 2900 | bicycling | 775 | jogging | 420 |
| hiking | 1250 | walking (brisk) | 530 | disco dancing | 335 |
| | | skating | 750 | table tennis | 175 |
| | | soccer | 1160 | | |
| | | volleyball | 750 | | |

*The figures in this table are averages for young adults.*

1. How many joules of energy would you get from one piece of pie?
2. How long would you have to jog to use up the energy from one piece of pie?
3. How long should you walk to use up the extra energy from a butterscotch sundae?

# 2

# Energy from Electricity

Every time we flick a switch or plug in a cord we instantly unleash a flow of invisible energy. Electricity comes only when summoned, and then it travels with the speed of light. We use it to process the food we eat, to produce the goods we use, to heat and cool our homes, offices, and factories, to light up our cities and towns, and to power the dozens of appliances that contribute to our high standard of living.

Electricity exists in nature, but not in forms we can use. Tiny discharges of electricity can be heard and may be seen when combing one's hair in a darkened room, and tremendous discharges occur between earth and clouds during thunderstorms. Electricity in a form we can use is produced by converting natural sources of energy. Some of the sources we use are more suitable than others. Ideally, we would like our electricity to meet these standards:

- cheap to produce
- plentiful supply at all times of the day, and in all seasons
- guaranteed supplies for the future
- no harmful side-effects

## How Does Electricity Work?
Activity
## How Does Static Electricity Work?

What causes the crackling sound you sometimes hear when you comb your hair? Why does walking on a rug and touching metal sometimes give you a mild electric shock? The following activity will help you answer these questions.

**MATERIALS** You will need a pill bottle, 15 cm of insulated #12 wire, some aluminum foil, a hammer, a 5-cm nail, a comb, a pair of pliers, a test tube or glass rod, a plastic rod, an aluminum rod (or rod made of any other metal), some silk or nylon, some wool or fur, a cottage-cheese container with a lid or a glass jar with a lid, and a pair of scissors.

**PROCEDURE** To detect charges of static electricity, build the metal-leaf electroscope, as shown here.

Set the flexible materials—nylon or silk, wool or fur, in one pile and the other materials in a second pile.

Bring the comb to the bare-wire loop of the electroscope. Watch the foil for movement.

Run the comb through your hair and repeat the previous step.

Rub each of the objects with each of the soft materials and test with the electroscope. Record each result.

Touch the bare-wire loop of the electroscope between tests to neutralize it.

Try to get a spark by rubbing the comb or glass as before and then bringing it to a metal radiator or water tap.

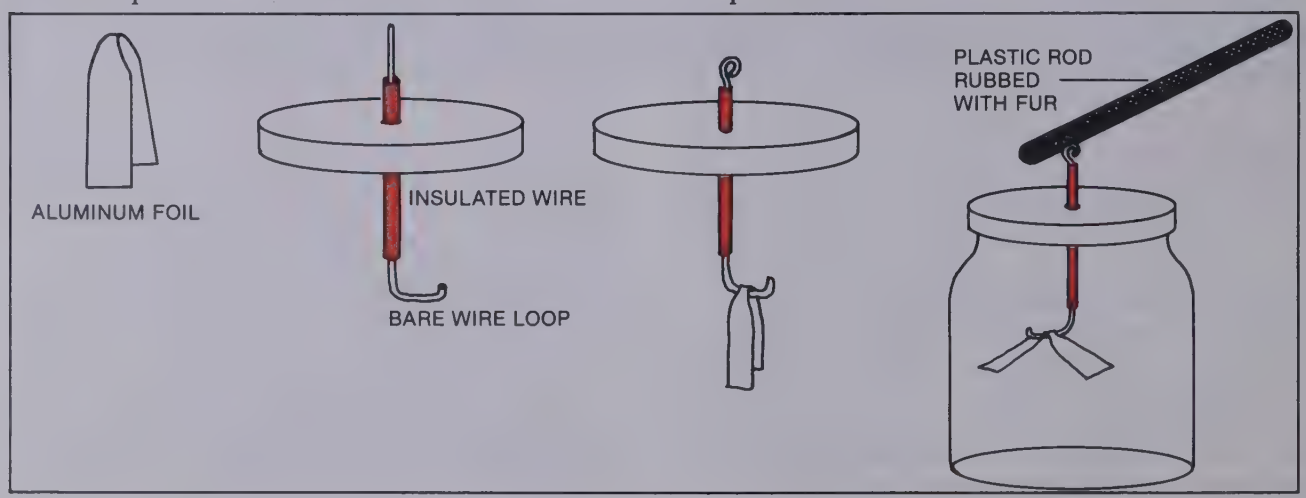
**OBSERVATION** Prepare a table of observations in your notebook. Record your observations.

| MATERIALS RUBBED TOGETHER | AMOUNT OF DEFLECTION OF THE LEAVES OF THE ELECTROSCOPE |
|---|---|
| | |
| | |
| | |
| | |

**CONCLUSION** Rubbing the objects charged them with static electricity. Which combination produced the strongest charge of static electricity?

Why does a spark jump to the water tap or radiator when you bring a charged object near it?

1. Sometimes when you walk across a rug and then touch something, you hear, and perhaps see, a spark. Explain what is happening.
2. Lightning is a very large spark of the same kind of electricity. Find out about Benjamin Franklin and his kite if you don't know the story. Find out what a lightning rod is and how it works.
3. The movement of tires on pavement builds up static charge in a moving vehicle. Perhaps you have felt a mild shock when you stepped out of a car. When the vehicle is a tank truck carrying gasoline, there is a possibility of a static charge setting off an explosion. Find out how this is prevented.

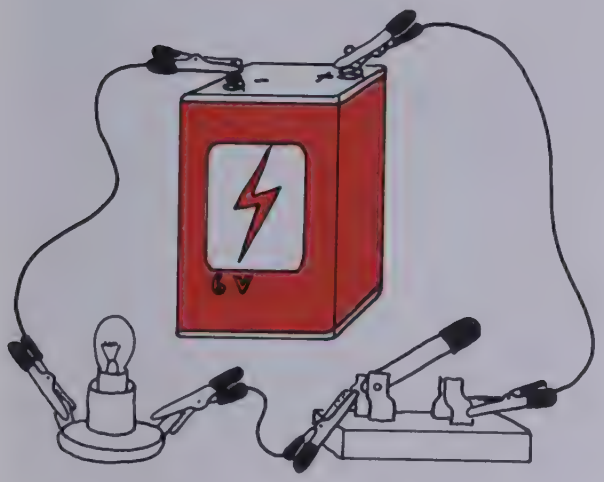


Activity

## How Does an Electric Circuit Work?

This activity will help you to demonstrate what is meant by *circuit*.

**MATERIALS** You will need a large 6-V (volt) battery or 4 1.5-V flashlight dry cells and a holding assembly, 3 pieces of #18 braided wire, each about 20 cm long with alligator clips attached, a 6-V bulb in a socket, and a knife switch.




**PROCEDURE** Try to connect the battery and the lightbulb with the wires so that the bulb glows.

Connect the wires so that the switch is part of the circuit. Open and close the switch to see that it works.

Connect the wires so that the switch is in the circuit, but in a different position. Test to see that the switch works.

Connect the switch to the lamp without the battery and see if the bulb will glow.

**OBSERVATION** Make a sketch of each successful circuit you connected.

**CONCLUSION** In your own words, what is necessary in order to have an electric circuit?

Activity

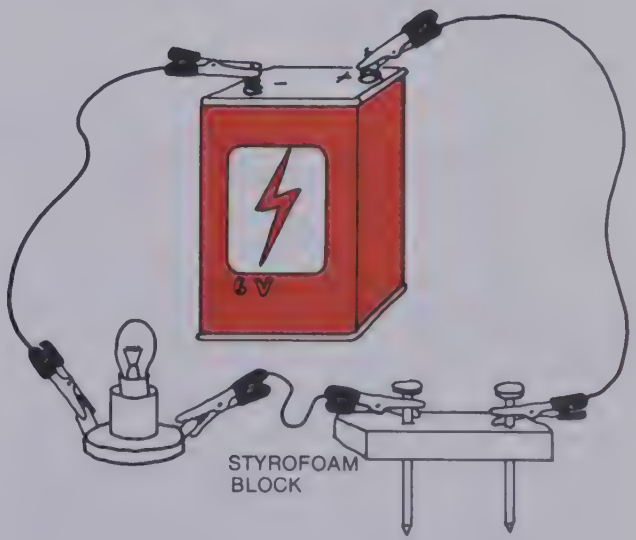
## Which Materials Are Conductors of Electricity, and Which Materials Are Insulators?

You can answer this question by making a tester.

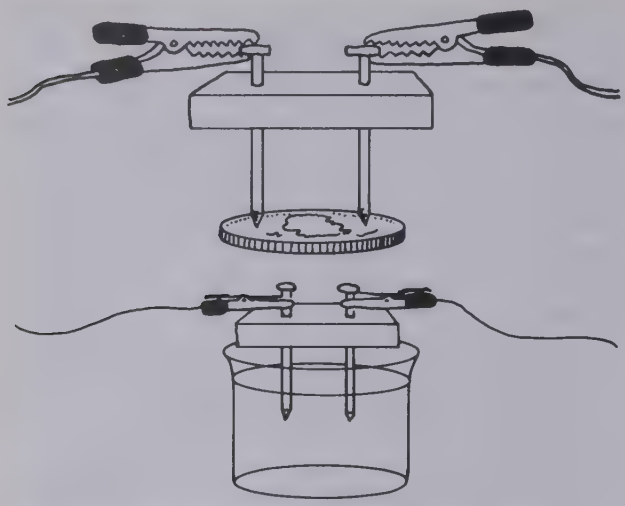
**MATERIALS** You will need a dry cell, or flashlight batteries, a bulb and socket, a Styrofoam block about 2 cm × 8 cm × 8 cm, 2 nails, 4 beakers, 3 pieces of wire, each about 20 cm in length with alligator clips attached.

Materials to test include: aluminum foil, leather, chalk, paper, glass, cloth, key, lead pencil (sharpen the pencil at each end), toothpicks, nails, paperclip, penny, nickel, dime, quarter, plastic comb, eraser, distilled water, salt solution, sugar solution, vinegar solution, tap water, carbon core from a flashlight battery.

The conductivity tester is not sensitive enough to distinguish between poor conductors and insulators. *Some substances on your list of insulators actually conduct electricity well enough to give you a severe shock if a voltage of* 110 V *is applied.*



**PROCEDURE** Connect the circuit as shown here.



The space between the tips of the nails acts as a switch.

Test your circuit to see if it works. (What is it neccesary to do?) *The electricity from the battery is harmless, and is all you need to test these materials. Do not use the electricity from wall outlets. It can be dangerous to do so.*

Touch the nails to each end of a piece of aluminum foil. Does the bulb light up? Aluminum is a conductor of electricity.

Touch the nails to each end of a piece of leather. Does the bulb light up? Leather is an insulator.

Test each of your materials in turn. Classify them as conductors or insulators.

**OBSERVATION**

| CONDUCTORS | INSULATORS |
|---|---|
| | |
| | |
| | |
| | |

**CONCLUSION** What can you conclude from your observations?

All materials will conduct some electricity. The materials that conduct very little are the insulators. The towers that hold up high-voltage wires are made of steel for strength. The wires that carry the powerful currents of electricity are separated from the steel towers by insulators. What material would you guess is used for these insulators?

## Activity
### How Does an Electric Lightbulb Work?

The lamp you make in this activity works on the same principle as a real lightbulb.

**MATERIALS** You will need a wide-mouth jar or bottle, a Styrofoam block about 2 cm × 8 cm × 8 cm, 2 nails about 8 cm long, 4 strong dry cells or a strong 6-V battery, 3 pieces of wire, each 20 cm in length, with alligator clips attached, a knife switch, Plasticene, braided copper lamp wire and braided iron picture wire.

**PROCEDURE** Push the nails through the Styrofoam block, 1 cm apart. Secure the nails with Plasticene if they are loose.

Separate a strand of the braided iron wire, 8 cm long. Attach the ends of the wire to the 2 nails, by giving the wire two or three twists. There should be a 1-cm strand of straight wire between the twisted knots on the 2 nails.

Connect the circuit as shown here and close the switch. Observe the wire in the jar. If you do not get the wire to glow, pinch the points of the nails together to make the wire draw tightly against the nails. *Do not touch the hot filament! The melting point of iron is* 1535°C.

Try using 2, 3, or more strands of iron wire to make the coil.

Try using a single strand of copper wire.

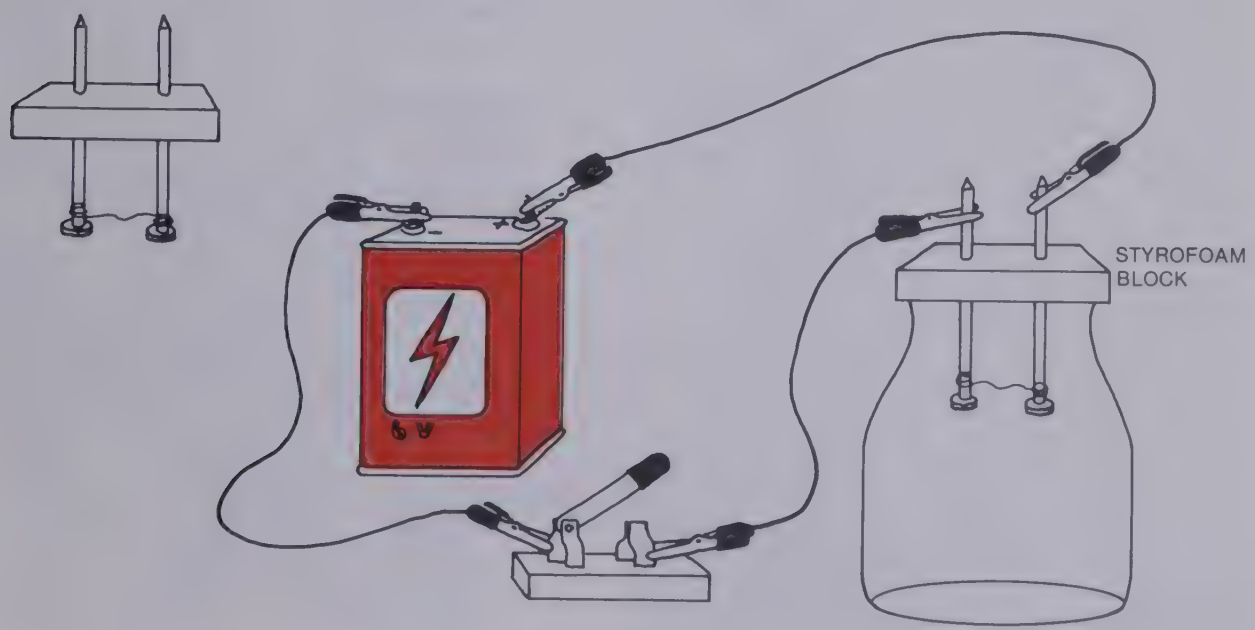
**OBSERVATION** Record your observations in a table.

| TYPE OF WIRE | NUMBER OF STRANDS OF WIRE USED | BRIGHTNESS OF GLOWING WIRE | DURATION OF GLOWING (SECONDS) |
|---|---|---|---|
| IRON | 1 | | |
| IRON | 2 | | |
| IRON | 3 | | |
| IRON | 4 | | |
| COPPER | 1 | | |

**CONCLUSION** Did the number of strands used affect the length of time the wire glowed? the brightness of the light produced?

Did the kind of wire used have any effect?

**EXTENDED CONCLUSIONS** What makes the lightbulb glow? What happens when a lightbulb burns out?



## Power and Watts

Lightbulbs and other electrical appliances that you use at home are rated in watts. A 60-W (sixty watt) lightbulb will convert 60 J (joules) of electrical energy, each second, into light, heat, and sound. A 100-W lightbulb will convert 100 J of electrical energy each second. When the two bulbs are compared, the 100-W bulb makes a brighter light. It converts more electrical energy each second. The 100-W bulb has more power.

Power is the capacity to convert energy. The energy converter with the shovel shown here has enough power to move the pile of earth if he is given enough time. If we are in a hurry, we need a machine that can convert energy more quickly—a machine with more power, like the bulldozer.

The worker with the shovel would have a power rating of 100 W to 150 W. The power of the bulldozer is still measured in horsepower, a word left over from the days when horses provided the power for heavy work. A real horse has a power rating of about 500 W, but for the power rating of motors and engines, it has been agreed that one horsepower equals 746 W.

1. The bulldozer in the illustration converts fuel in a hurry and may be rated at 600 HP (horsepower). How many watts is that?
2. How many people are needed to provide the one horsepower?

Activity

## How Is Magnetism Related to Electricity?

This activity will help you understand how magnetism is an important part of understanding electricity.

**MATERIALS** You will need 2 bar magnets, a retort stand and retort ring, a jumbo paperclip, some string, a compass, some iron filings in a shaker bottle, and a sheet of unlined paper.

**PROCEDURE** Suspend a bar magnet in a sling made from the large paperclip.

Bring the N end of the second bar magnet to the S end of the suspended magnet and observe the result.

Bring both ends marked N together and observe the result. Bring both ends marked S together, and observe the result.

Suspend a second magnet with a 1-m length of string. Give the magnet a gentle spin and let it come to rest. Check with the compass to find which way the magnet is pointing.

To show the existence of the invisible magnetic field that surrounds a magnet, lay a bar magnet flat on a table with a sheet of blank paper over it.

Sprinkle the paper lightly and evenly with iron filings. Do not allow any iron filings to come in direct contact with the magnet.

When finished, carefully pour the filings from the paper back into the iron-filings container.

**OBSERVATION** How does the N end of a magnet react to the S end of a second magnet?

Describe how the magnets behaved when two N ends, and also when two S ends, approached each other.

What happened when the bar magnet was allowed to freely rotate?

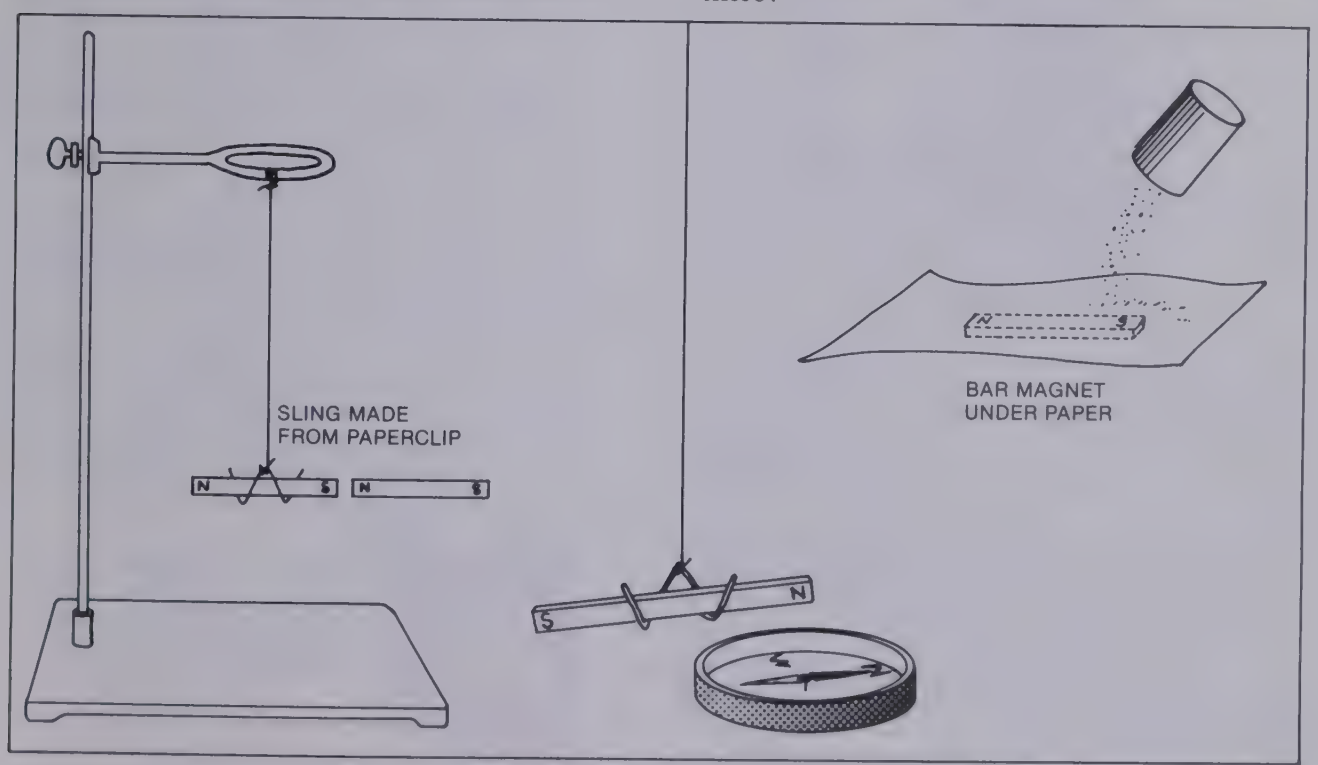
Make a diagram of the pattern of iron filings formed by the magnetic field that surrounds a bar magnet.

**CONCLUSION** Make a general statement regarding the attractions or repulsions that exist between the ends of bar magnets.

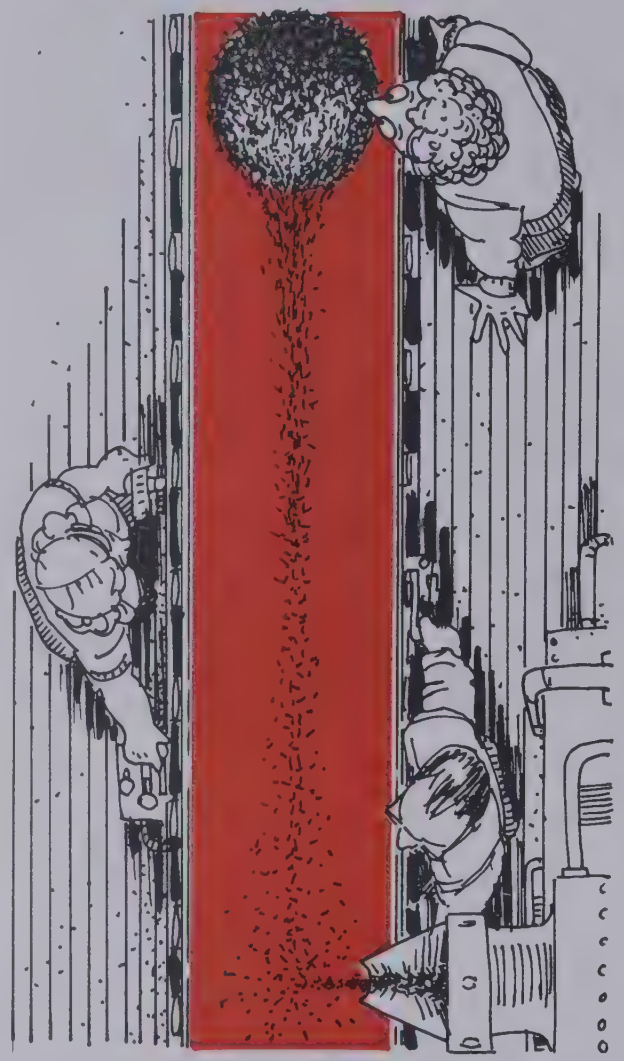
In what direction does the N end of a freely rotating bar magnet point?

How can you detect the invisible magnetic field around a magnet?

**EXTENDED CONCLUSION** If the N end of a bar magnet points to the geographic north of the earth, what kind of magnetic pole must be located there?



## A Sticky Problem



A machine in a shoe factory used tiny tacks to fasten the uppers to the soles. The tacks moved from storage along a moving belt. By the time the tacks reached the end of the belt, they were seen to stick together, as though they had become partly magnetized. The machine would not operate properly with these magnetized tacks.

The problem was solved when someone turned the machine 90°. In this position, the tacks showed no sign of being magnetized.

1. Explain why the tacks were magnetized.
2. Explain why turning the machine 90° solved the problem.

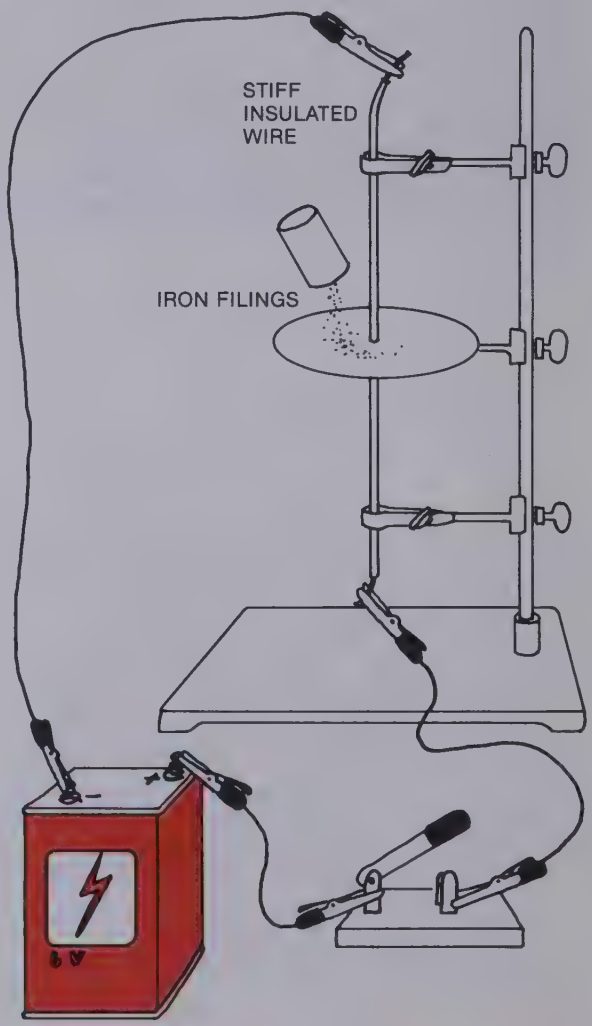
## Activity

### Does Electricity Produce Magnetism?

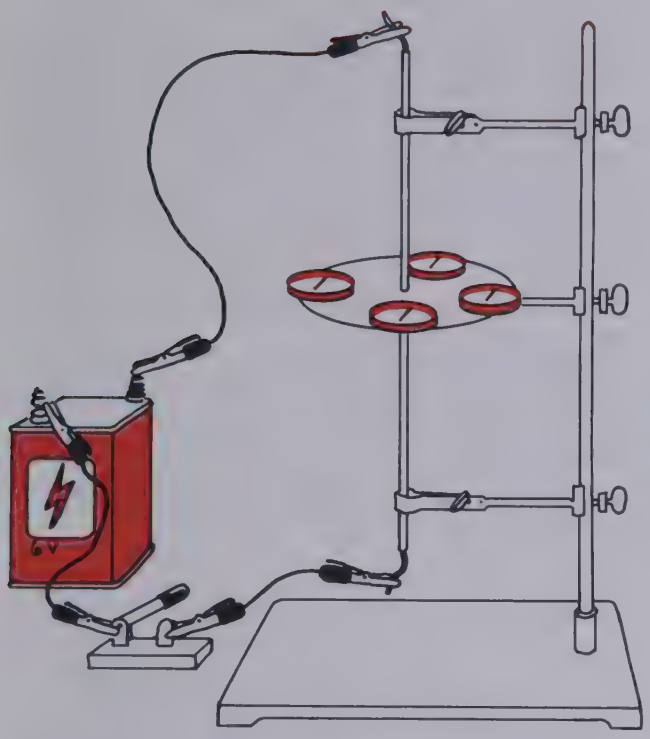
The effects of a magnet can be produced without using a magnet by doing the following activity. Your teacher will demonstrate, while you act as an observer.

**MATERIALS** Your teacher will need a powerful 6-V battery, a 1.5-V dry cell, a switch, a circular piece of stiff cardboard, 15 cm in diameter, some iron filings, a piece of stiff #12 insulated wire, 60 cm in length, 2 pieces of wire, 20 cm in length, with alligator clips attached, a piece of wire, 50 cm in length, 4 compasses, a retort stand and ring, and 2 retort clamps.

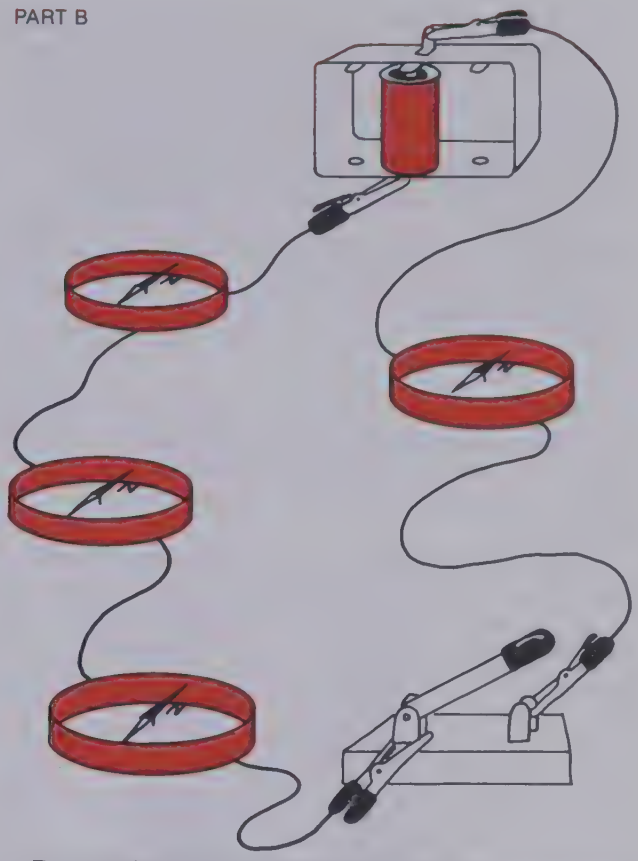
PART A



PART A



PART B



**PROCEDURE—PART A** *(for your teacher to follow)* Using the powerful 6-V battery, connect up the apparatus, as shown here for Part A. Leave the switch open.

Sprinkle a few iron filings onto the piece of stiff cardboard and observe the result.

Close the switch. Tap the cardboard gently and again observe the result. *Do not leave the switch closed. The battery will wear out quickly if you do.*

Remove the iron filings from the cardboard and place the 4 compasses on the cardboard around the wire. Note the direction the compasses point.

Briefly close the switch and observe the direction the compasses point.

**PROCEDURE—PART B** *(for your teacher to follow)* With the switch open, set up the apparatus, as shown for Part B, with the 4 compasses underneath the wires. Note the direction the compasses point.

*Briefly* close the switch. Watch the compass needles for any change.

Repeat the last two steps but place the compass on top of the wires. Use tiny pieces of paper on wooden splints to level the compasses so that they can rotate freely.

**OBSERVATION** What happened to the iron filings around the wire before the switch was closed and after the switch was closed?

What happened to the compasses around the wire before and after the switch was closed in the last two steps of Part A of the procedure?

In the last two steps of Part B of the procedure, what changes occurred in the directions the compasses pointed?

**CONCLUSION** Does electricity produce magnetism? How do you know?

Was the direction of the magnetic field lines consistent with the Left-Hand Rule? (The Left-Hand Rule states that if the thumb of your left hand is pointed in the direction the electrons are flowing in a wire, your fingers will encircle the wire in the direction of the magnetic lines of force. The north pole of a compass points in the direction the lines of force run.)

Activity

## How Can Electric Currents Be Detected?

By constructing this simple model of a galvanometer, you can attempt to demonstrate the detection of very weak electric currents. (This galvanometer will be used in the next activity.)

**MATERIALS** You will need a pocket compass, a rectangular piece of corrugated cardboard or thin wood about 3 cm × 18 cm, a 5-cm nail, 10 m of #20 bell wire, wire strippers, glue or tape, and a very weak 1.5-V dry cell.

**PROCEDURE** Fasten the compass to the center of the rectangular piece of cardboard using glue or tape. Have the compass aligned with its N-S direction perpendicular to the length of the rectangle.

Wind the 10 m of wire around the compass and cardboard in the N-line direction. With the nail, punch a small hole in the cardboard near each end. Insert the wires through the holes to hold them tight.

Strip away 1 cm of insulation from each end of the wire, using wire strippers.

Set up the galvanometer on some books or blocks, as shown here, so that the compass is level and free to rotate. Orient the galvanometer so that the N pole of the compass is over the N mark on the compass scale.

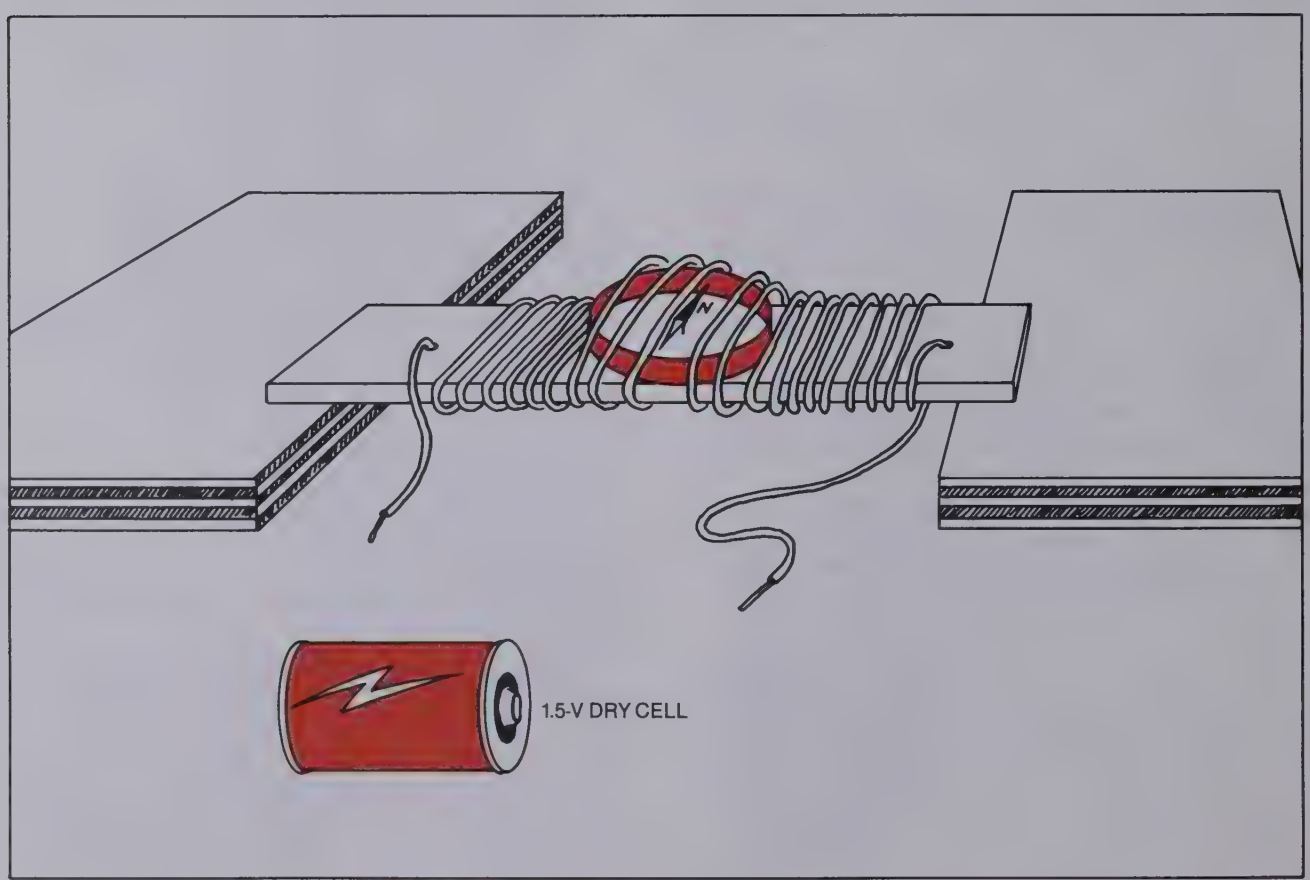
Test the galvanometer by touching the wires to a very weak flashlight dry cell. Watch the compass needle.

Reverse the connections to the dry cell. Watch the compass needle.

**OBSERVATION** What happened to the compass needle when you connected the wires to a dry cell?

What happened when you reversed connections to the dry cell?

**CONCLUSION** What makes the compass needle move when current flows through the wires?



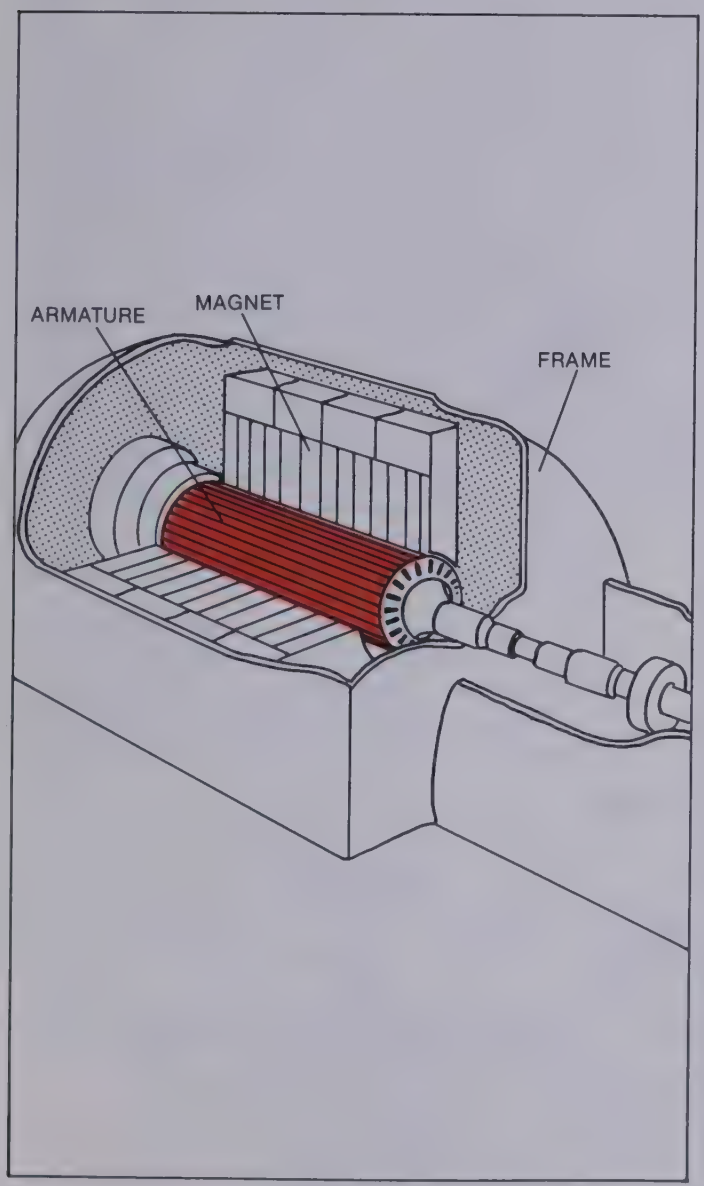
## How Is Electricity Produced? The Generator

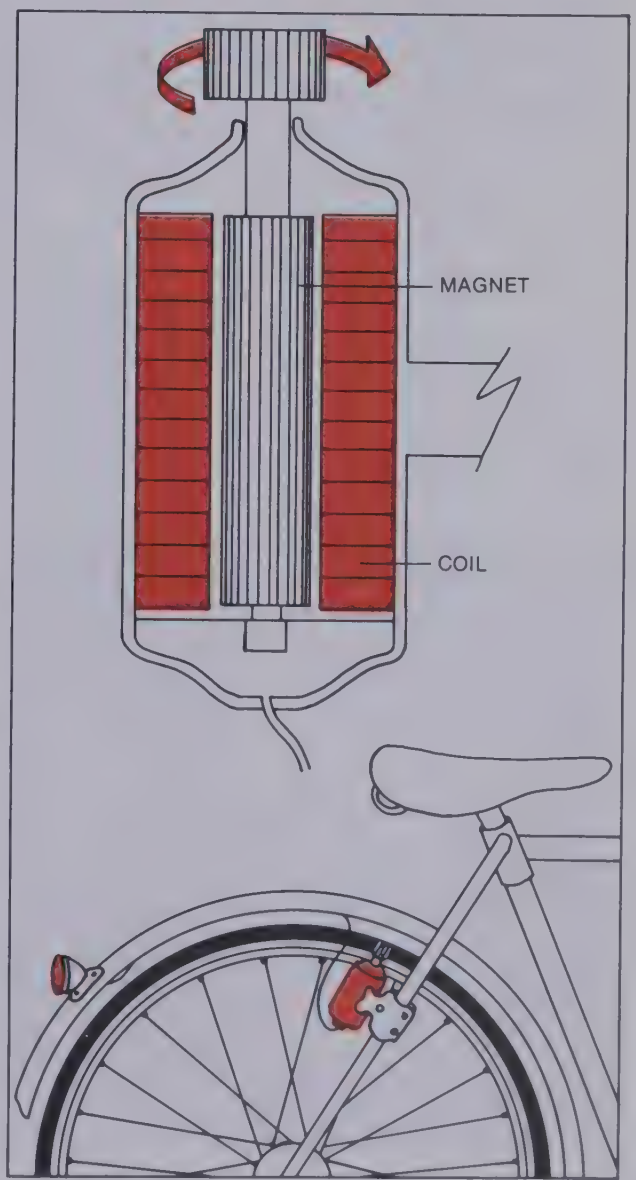
The heart of the system that produces electricity is the generator. This ingenious arrangement of wires and magnets looks much like an electric motor, but there is one important difference: a generator *makes* electricity.

The generator has basically just two important parts. One is stationary and the other one revolves. In the diagram shown here, heavy magnets are attached to the frame of the generator. The moving part, called the armature, is a drum wound with many coils of wire. When the armature spins inside the magnets, electricity flows from the wires.

A bicycle generator works on the same principle, but the parts are reversed. The coils of wire are fixed to the shell of the generator, and it is the magnet that is made to spin.

All we need to produce electricity, then, is a generator and a source of energy to make it spin.



## Activity
### How Does a Generator Work?

By doing this activity, you can construct a simple model generator and study the electric current it generates.

**MATERIALS** You will need a strong bar magnet, a cardboard tube about 20 cm long, 2 pieces of wire, 50 cm in length, with alligator clips attached, 20 m of #20 insulated wire, wire strippers, the galvanometer made in the preceding activity, an ammeter (with a 50-mA scale, if available), and a 5-cm nail.

**PROCEDURE** Wind 20 m of insulated wire around the cardboard tube. Keep the ends of the wire tight by piercing a hole near each end of the cardboard tube with a nail and inserting the wire ends through the hole. Use the wire strippers to remove 1 cm of insulation from each end of the wire.

Connect the wires to the galvanometer, using the wires with the alligator clips.

Move the magnet in and out of the tube. Observe the movement of the needle of the galvanometer.

Reverse the pole of the magnet that you insert and observe the result.

Move the magnet at different speeds. Observe the effect on the needle.

Hold the magnet steady. Observe the effect.

Pass the bar magnet right through the tube and observe the effect.

If a 50-mA ammeter is available, place it in your circuit in place of your galvanometer and repeat the steps above, beginning with moving in and out of the tube. How large a current can you generate?

**OBSERVATION** What happened to the galvanometer when the bar magnet was inserted into the tube?

What happened to the galvanometer when the magnet was withdrawn from the tube?

What happened to the galvanometer when the pole of the bar magnet inserted into the tube was changed?

How did moving the magnet at different speeds affect the galvanometer?

What happened when the bar magnet was held steady?

What happened when the bar magnet was passed right through the tube?

If you used an ammeter, did you observe the same changes in direction of deflection as occurred with your galvanometer?

What was the maximum current you produced with your generator?

**CONCLUSION** What conditions are necessary to produce an electric current with a magnet and a coil of wire?

What happened to the direction the current flowed when you inserted and then withdrew the magnet? How do you know?

**EXTENDED CONCLUSIONS** Predict what would happen if you were to repeat the procedure by moving the coil of wire and holding the magnet steady.

Predict what the galvanometer would show if you were to use twice as much wire.

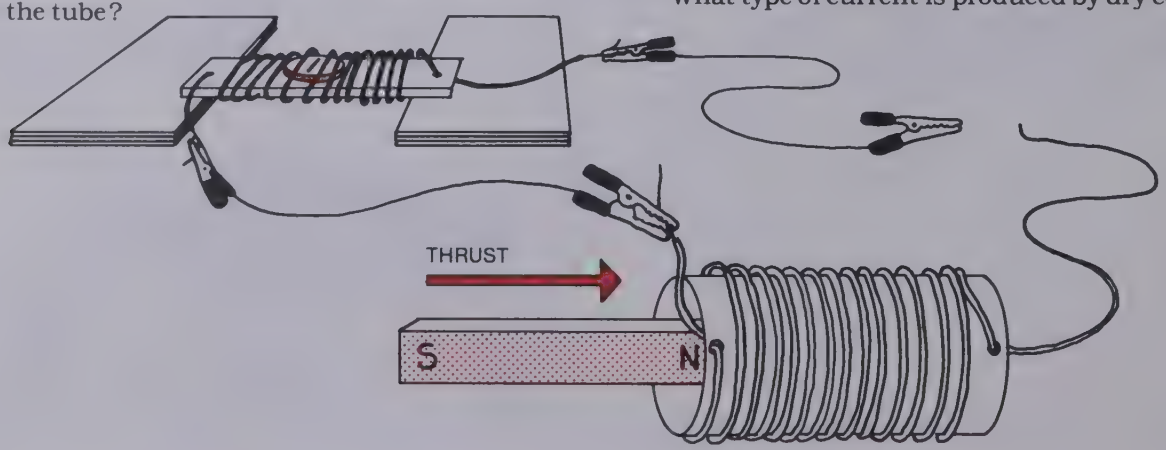
Predict what the galvanometer would show if you were to use a stronger magnet.

What is the difference between a direct current and an alternating current?

What kind of current did you produce when you repeatedly inserted and withdrew the magnet?

What type of current do electric-utility companies supply to homes and factories?

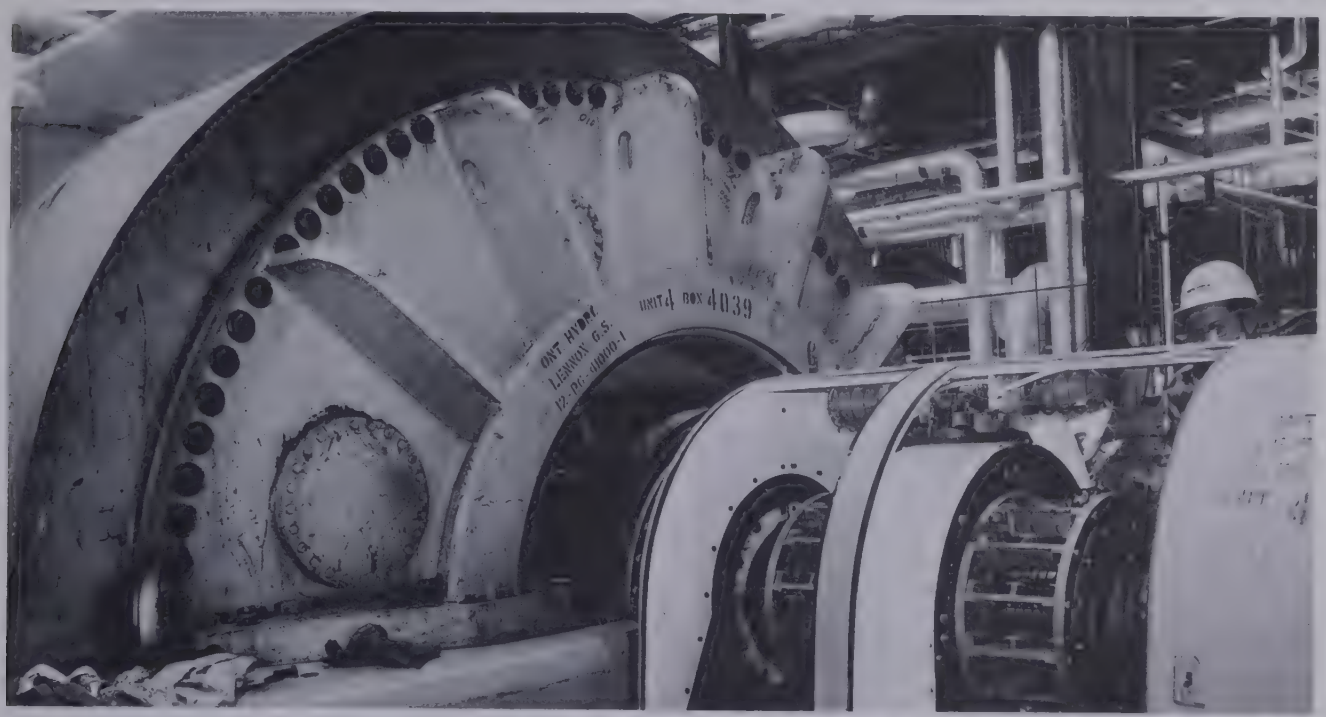
What type of current is produced by dry cells?



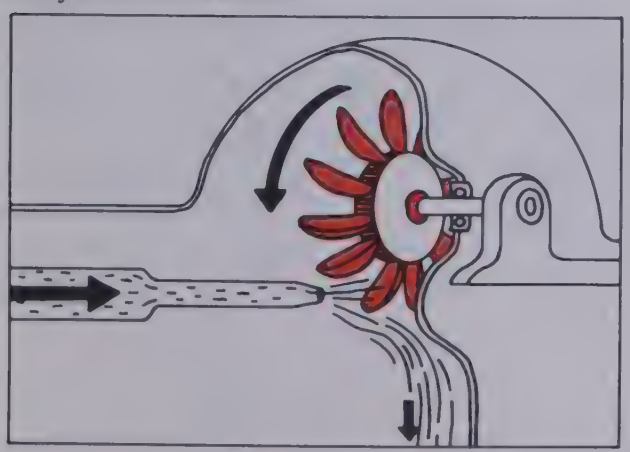
## The Turbine

The photograph shows an electrical generator, ready to produce electricity. All it needs is a steady supply of energy to make it turn. Such sources of energy include falling water, coal, oil, and uranium.

How can the energy of falling water, or the energy stored in coal, oil, or uranium, be used to turn a generator?




The machine that does the job is a development of an ancient invention, the waterwheel. In the diagram shown here, flowing water fills the buckets and the wheel turns. This modern version of the waterwheel is called a turbine. Turbines are designed to be turned by the force of flowing water or by the force of steam.



## Activity

### How Can Falling Water Generate Electricity?

You can't convert enough energy from falling water in the classroom to generate electricity, but you can convert the pressure in the water supply to do some work.

**MATERIALS** You will need a 250-mL milk carton, a wire coat hanger, a pencil without an eraser, a pair of pliers equipped with wire cutters, a razor blade or craft knife, 4 wooden tongue depressors about 2 cm × 9 cm, 1 m of strong thread, a stapler, some paperclips or a set of masses, a brick, a source of water, a floor mop, and a reduction nozzle for a water tap.

**PROCEDURE** Follow the arrows on the diagram, as shown here, to make the simple water turbine.

Try out the turbine and adjust the tension in the wire support so that the turbine turns freely.

Hold the turbine at different distances below the tap. Observe the effect on the speed of rotation.

Tie the thread to the pencil axle, near the bottom of the milk carton. Attach a paperclip to the other end of the thread.

Send a small flow of water over the turbine (just enough to turn it) and watch the turbine lift the clip.

Experiment with increasing and decreasing both the number of paperclips (load) and the water pressure. When the turbine is lifting a heavy load, you may have to give it a spin to get it started.

To increase the water pressure, add a reduction nozzle to the water tap.

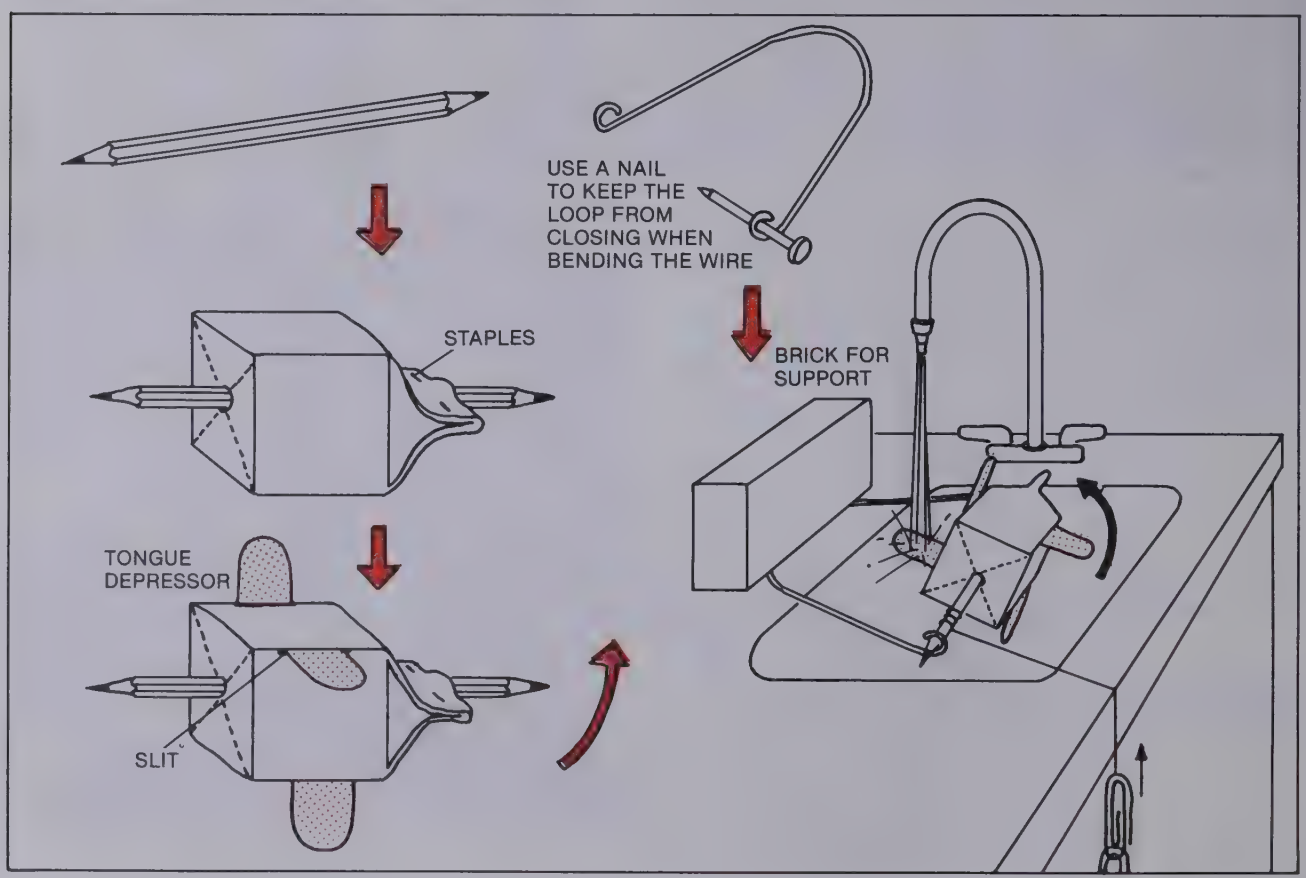
Wipe up any spilled water with the mop.

**OBSERVATION** What effect does the distance the water falls have on the speed of rotation of the turbine?

What happens when you increase the water pressure?

How many paperclips or grams of mass can the turbine lift?

**CONCLUSION** Write statements about this activity in which you use the words *water, pressure, turbine, load, energy, convert* (or *conversion*).



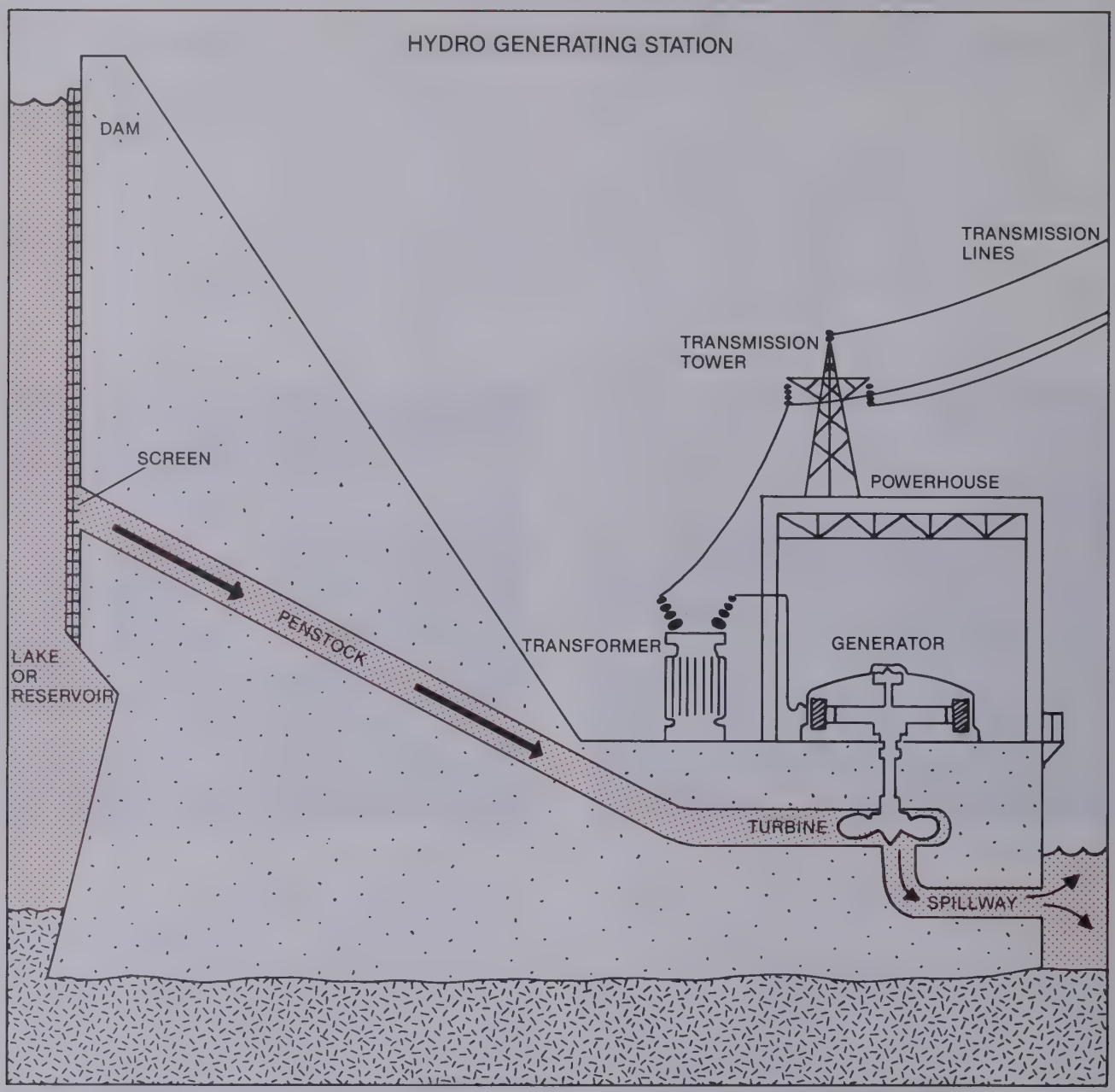
# 3

# Producing Electricity from Hydro Resources

Hydroelectric-generating stations can be built wherever a river with a great volume of water changes its height rapidly over a short distance. A waterfall or rapids can be an ideal location. When a site has been selected which meets these conditions, a dam is built to store the water. First a separate channel for the river is dug, or blasted from the rock, and the river is diverted. Then a massive dam is built of concrete and earth and rock fill. Millions of cubic metres of fill may be needed for the structure, and it may be several years before all the material has been hauled into place. When the dam is complete, the diversion channel is closed and the river flows again in its original channel.

The natural flow of rivers changes with the seasons and this makes rivers unreliable as a water supply. The storage area, or reservoir, behind the dam provides what rivers cannot—a constant flow of water that does not depend on the seasons. During the dry time of year, the level of the reservoir goes down, but there is always enough water to keep the production of electricity constant. During heavy rains, the reservoir fills up again. If more water enters the reservoir than is wanted, as might happen during spring floods, the extra water is released through a gate into the spillway.

Some reservoirs hold so much water that they can take years to fill up. When they do, the water extends for many kilometres. On maps, it may be called a lake. Large reservoirs create areas for boating and may also provide flood control for the river. The heavy runoff that formerly flooded the banks of the river is trapped behind the dam in the spring and then released slowly in the summer in small amounts that do not cause floods.




The generating station, where the turbines and generators are installed, is a building located at the base of the dam. A large pipe, the penstock, carries water from the reservoir to the turbines. Screens cover the penstock opening to prevent floating objects, such as logs, from entering the system. The water flows into the penstock and races down the long slope. At the bottom, it meets the blades of the turbine with great force and makes the turbine spin. A generator is attached to the turbine, and it is also set turning.

The number of turbines and generators installed depends on the amount of water the reservoir can supply. A very small hydroelectric plant may have only one generator. When the James Bay project, now under construction in Quebec, is complete, 37 generators will be in operation.

The electricity that is produced leaves the generating station by heavy wires strung on transmission towers. The wires are made of copper or aluminum because both are very good conductors of electricity. Both offer some resistance to the passage of electric current —all materials do—but very little. The electricity is kept from flowing from the wires to the metal towers by insulators. An electrical insulator is made of a material that offers great resistance to electricity. Large ceramic insulators are used on the transmission towers because the wires may carry a current at 200 kV. (Household electricity is 110 V.)

1. How is the water level in the lake reservoir of the hydroelectric project controlled?
2. Where are the turbines located?
3. Write a brief explanation of how the energy of water stored in the reservoir is converted to electrical energy.
4. Why is hydroelectric power considered to be a renewable resource?

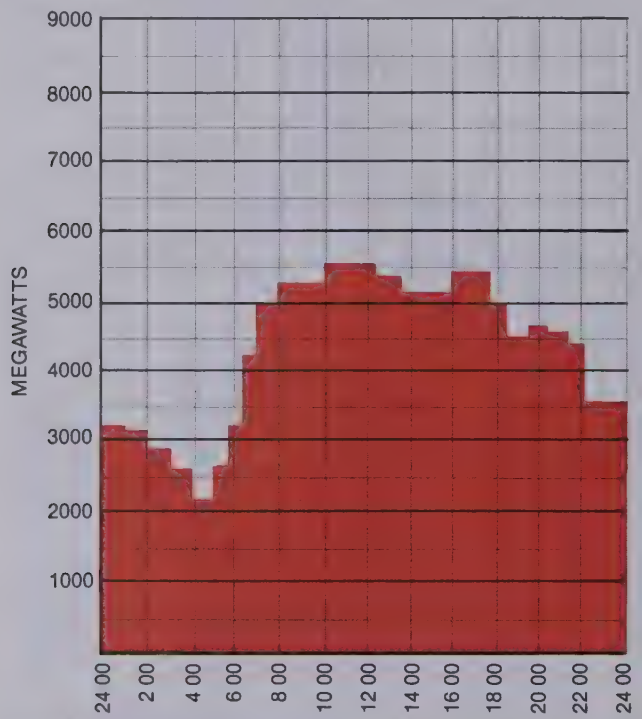
## Advantages of the Hydroelectric System

There are advantages of the hydroelectric generating system, besides providing water for irrigation and controlling floods. A hydroelectric station is cheap to operate. Unlike a factory that has to pay for its raw materials, the hydroelectric plant gets its raw material—flowing water—free. Construction of the dam and power plant needs many workers, but once construction is complete, only a few engineers and technicians are needed to keep the plant running. Their job is mainly one of regular inspection to see that water levels are correct and the turbines and generators are running as they should.

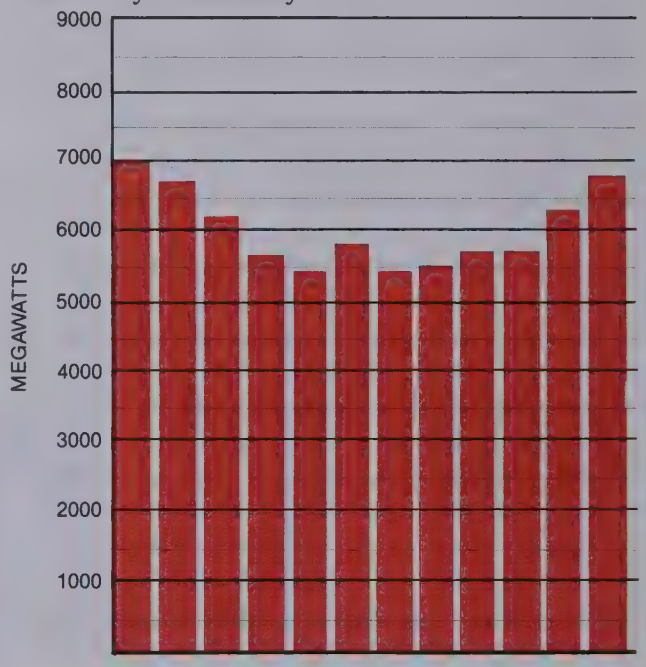
Hydroelectric plants tend to be massive and huge, but they use large, simple machines that last a long time. A hundred years from the time the turbines start spinning, the hydroelectric plant could still be producing electricity.

Another advantage of this system is that no fossil fuels are needed. This means that petroleum and coal supplies can be used for other purposes. It also means that there are no harmful combustion products or wastes of any kind. The water that flows through the turbine is not changed or polluted. After doing its work, the river continues on its way downstream and ends up in the sea.

A very useful feature of the hydroelectric system is that the flow of water is adjustable. A control valve on the penstock can be partly closed, just like a water tap. This slows down the turbine and the generator, and less electricity is produced. The following graphs show why a flexible output of electricity is necessary.




SUMMER PATTERN OF DAILY ELECTRIC POWER DEMAND




YEARLY PATTERN OF MONTHLY ELECTRIC POWER DEMAND

1. Why does the demand for electricity change with the time of day?
2. Daily demands are greatest at two times of the day. What are they? Why is more electricity used at these times?
3. Find the time of lowest demand on the daily-demand graph. Why is demand lowest at this time of day?
4. Demand for electricity varies not only with the time of day, but also with the season. The demand curve for the year, shown on the monthly-demand graph, is fairly regular. The months have not been entered on the graph. Name two months when you think demand for electricity would be greatest. Name two months when you think demand would be least.

## Disadvantages of the Hydroelectric System

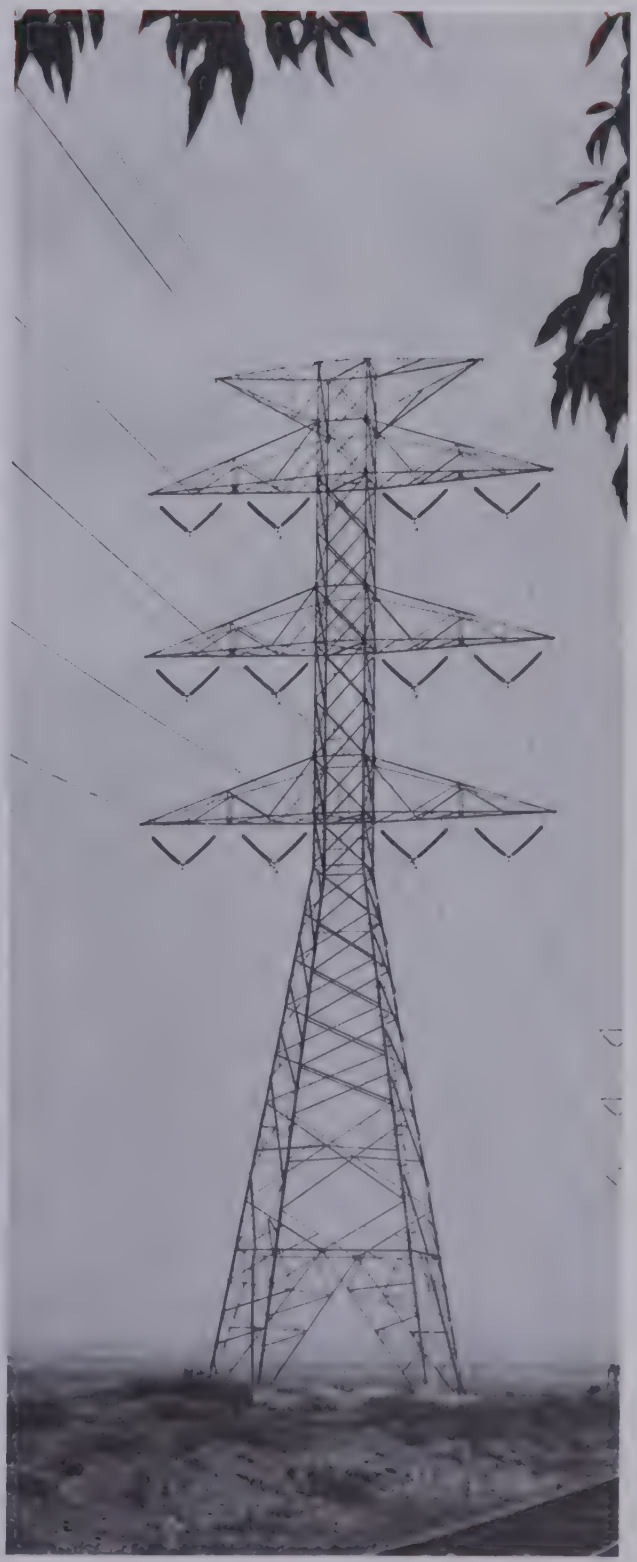
The costs of starting up a new hydroelectric generating station can be measured partly in the number of dollars needed to build the plant. There are other costs as well, some of them hard to evaluate, but still important and real.

**Transmission Corridors** Hydroelectric sites are usually some distance from the cities that buy the electricity. Thousands of kilometres of wire are needed to bring the electrical energy to consumers. The wires could be buried in the ground, but the cost would be too great. The only practical method is to string the transmission lines on tall steel towers.

Some people object to the sight of transmission towers stretching across the landscape. Others object to the amount of land that is taken up by a transmission corridor. In Ontario, for example, the opposition from a group of farmers and landowners has held up construction of a transmission corridor for years.

**Electromagnetic Radiation** Another question about transmission lines concerns health and safety. If you walk under a transmission line carrying a fluorescent light, the tube will light up. This is because not all of the electrical energy stays in the wires. Enough electromagnetic radiation reaches the ground to make the light glow. This amount is harmless, but there is still the question of what happens to people who are exposed to this kind of radiation over a long period of time.

Electromagnetic radiation from transmission lines is a controversial topic. Some studies reject the idea that harm is possible, and others say more investigation is needed. One reason for the uncertainty is that effects on people, if there are any, do not happen suddenly, as in the case of a burned finger resulting from touching a hot frying pan. Long-term effects may not show up for years. By then, it may not be easy to determine the precise cause.



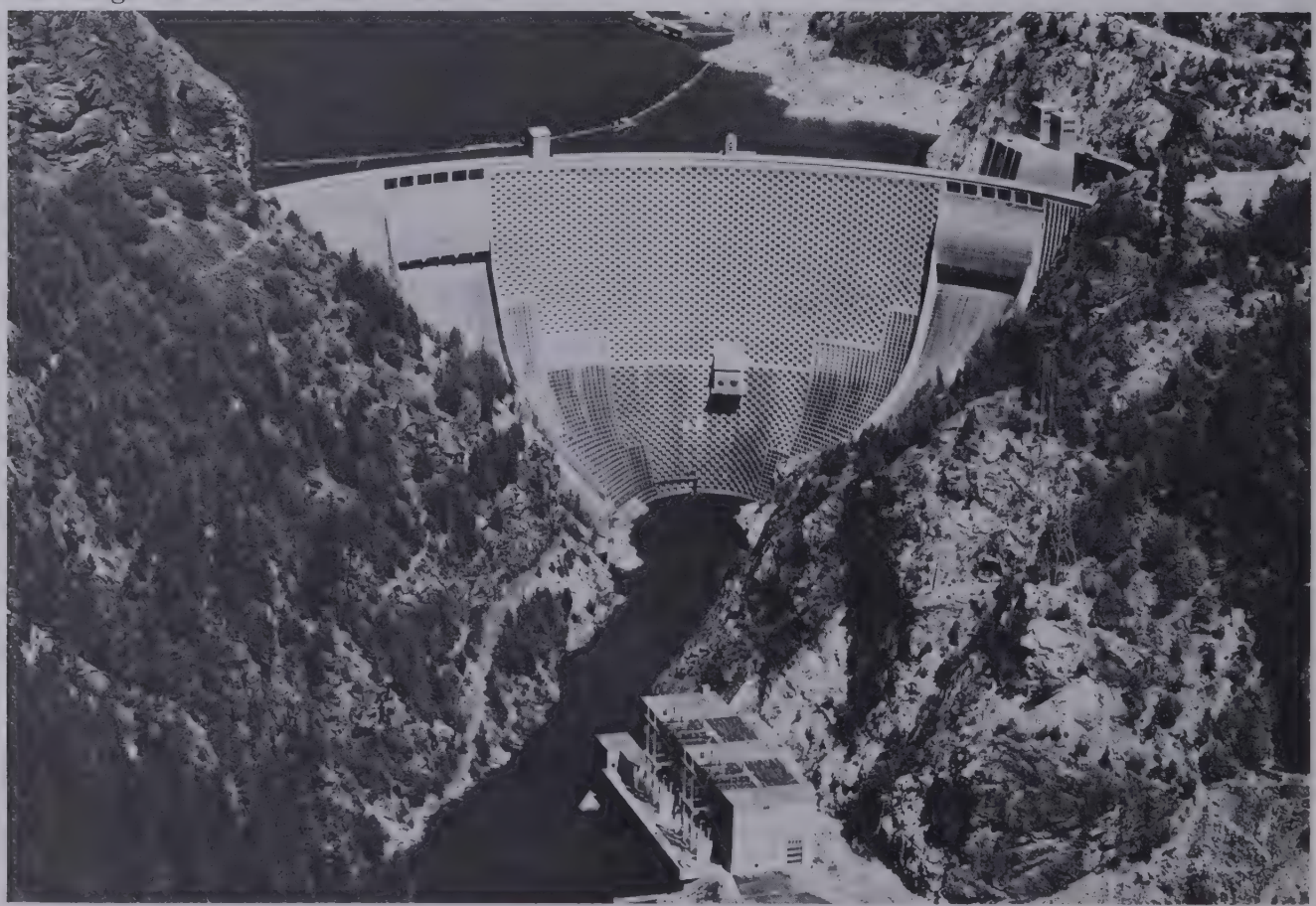
**Dams** Conservationists have objections to dams. A dam disrupts life in a river, both below the dam and above it. Fish that normally spawn (reproduce) upstream are prevented by the dam from doing so, unless special "fish ladders" are provided. Changes in water levels and changes in the rates of flow can disrupt marine life in the river downstream from the dam.

**Reservoirs** Above a dam, a reservoir covers forever a large expanse of land. Although the body of water may be called a "lake," it will be unlike any lake you have seen. The changes in water level may leave shores that are dead and muddy and covered with rotting logs and other debris. It may not be an attractive place for a picnic, but if nobody ever goes there, that may not matter.

Sometimes the drowning of a valley does matter. In the western part of Canada and the United States, two groups of people are trying to control the future of part of the Skagit River. The Skagit River begins in the mountains of British Columbia, flows across the border into the state of Washington, and then into Puget Sound, near the American city of Seattle. Seattle is a city that wants more electricity. Hydroelectric dams have already been built on branches of the Skagit River on the American side. The reservoir created by the Ross Dam, called Ross Lake, extends across the border into Canada and floods part of the Canadian Skagit Valley.

Now the city of Seattle proposes to raise the height of the Ross Dam. If this is done, Ross Lake will extend some 15 km into British Columbia and flood more than 200 ha of valley land.

The Skagit Valley is about 20 km long and 2 km wide. It is a flat-bottomed valley, which is rare in this area. In a mountainous area, valleys tend to be narrow gorges. This valley is wide, and rich in wildlife and mountain scenery. To outdoors people and conservationists, the Skagit is a beautiful valley that must be preserved.



**Displaced People** The second-largest hydroelectric project anywhere is under construction now along the east side of James Bay in Quebec. When it is complete, it will have eight of the world's largest dams, 1000 km of new roads in a wilderness, and 37 generators. It will affect a drainage area of 176 000 $km^2$ and create a reservoir twice the size of the province of Prince Edward Island. This tremendous accomplishment of builders and engineers will create electrical energy for expanded industry in the province of Quebec and will also create a surplus for sale to the United States. Huge amounts of money are at stake, and the government of Quebec, which owns the James Bay project, sees it as a good investment. As electricity is sold, money will come into the province and the people of the province are expected to benefit.

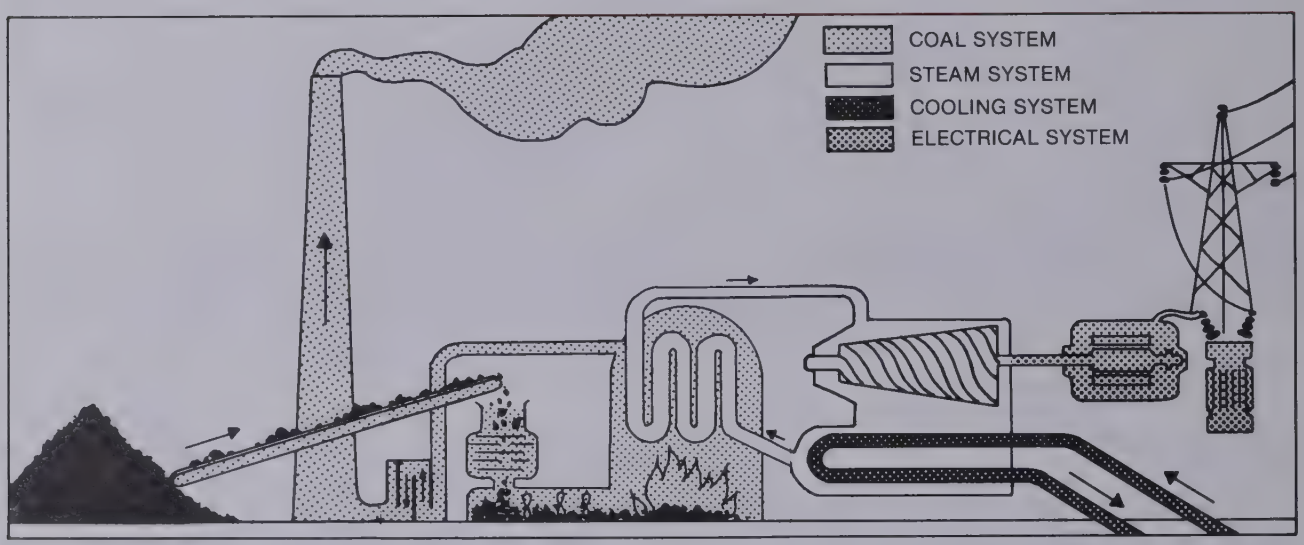
Part of the cost of the project is payment made to the native people who lived in the James Bay region taken over the hydro project. There are about 8000 of them, Cree Indian and Inuit. For many centuries they lived in this region, following a lifestyle with values very different from those of the builders and engineers. They hunted, fished, and trapped. They tried to take only what was needed from the land—trying to live in balance with nature.

To make up for the disruption of their lives, the native people were paid money in amounts that were judged by the courts to be fair. Some of the people were pleased, usually the younger members of the group. Some who were not pleased said, "We have always known a life in which everything is shared, moving about freely without an accumulation of possessions. Money does not last. It comes, it goes. But the land remains always. If you destroy the land, you destroy the Indian."

1. Transmission towers are not as pretty as trees, but some are necessary. Would you be willing to have one on your property? Do you think that anyone should object to the construction of new transmission corridors? Explain your answer.
2. Is damage to fish life in a river an acceptable price to pay if we get a hydroelectric plant in exchange? What is your opinion?
3. State the problem that is raised by large hydroelectric developments that disrupt the lives of people. What solution do you suggest for the problem?

# 4

# Producing Electricity from Thermal Energy




People who live in regions that have rivers and waterfalls are fortunate. Once a dam is built to store energy and water turbines are installed, generators can be made to produce electricity for the consumers. Some areas do not have the necessary water resources. To produce electrical energy, they must begin with the energy stored in coal, petroleum, or uranium.

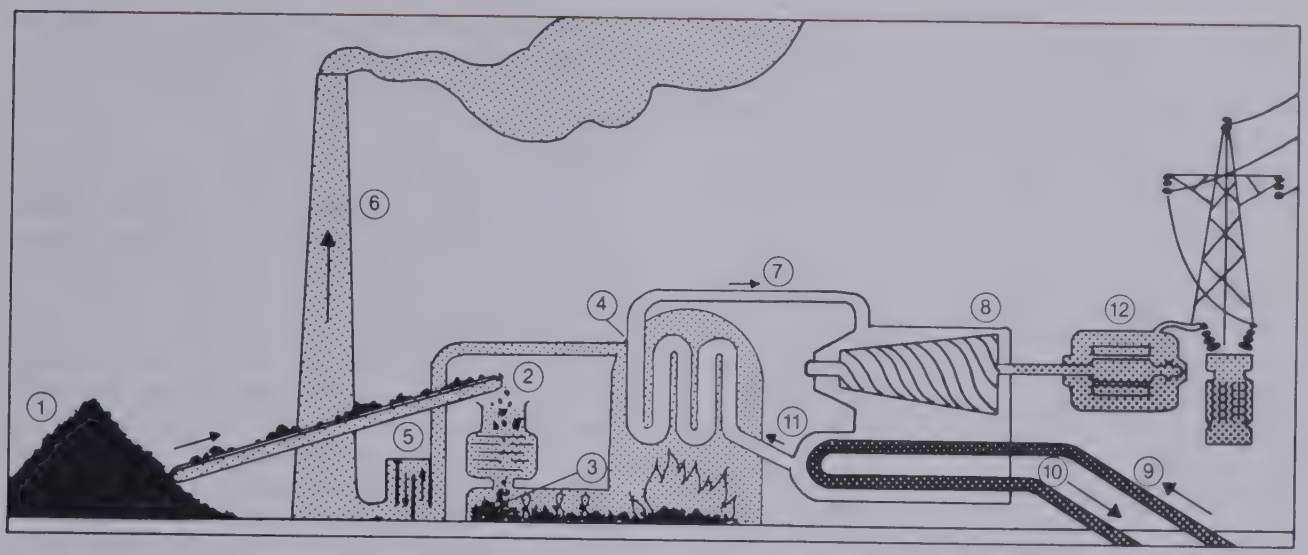
Thermal-electric plants may burn coal, oil, natural gas, or uranium (in a nuclear reaction) to release heat energy. Oil, natural gas, and uranium do not produce ashes or exactly the same waste products as does coal, but other than those minor differences, the thermal-electric plant is basically the same for all four fuels.

## Thermal-electric Power from Fossil Fuels

Coal, oil, and natural gas, all contain heat energy, and that heat energy can be converted into electrical energy. This is done in a thermal-electric plant.

If coal is the fuel, it is first pulverized into a fine powder. The powder is mixed with hot air and the mixture is blown into a boiler where it burns instantly and completely. The heat given off boils water and makes steam.

When coal burns, it leaves ashes. Bottom ash falls to the floor of the firepit where it can be easily removed. Most of the ash waste, however, is fly ash —particles that are so small they float up the




smokestack with the exhaust gases. Almost all of the fly ash can be removed with a precipitator. The exhaust gases are passed over electrically-charged plates. The tiny particles of fly ash cling to the plates. When the plates are rapped mechanically, the fly ash falls into a collecting bin.

After the water in the boilers turns to steam, the steam is superheated and fed to giant turbines. Steam turbines have a different shape than water turbines. A steam turbine has many thin blades. If you have ever blown on a fan, you have seen how the blades can be made to move and spin around. Pressurized steam does the same thing to the turbine blades, only more efficiently. The steam rushes into the turbine under great pressure and it forces the blades around very rapidly. The tips of the blades whirl around at speeds of up to 1760 km/h—faster than the speed of sound. As the shaft holding the blades revolves, it spins the generator and electrical energy is produced.

After the steam spins the turbine, it goes to the condenser. Here the pipes carrying the steam are surrounded by cool water. The steam condenses in its pipes to liquid, and this hot water is returned to the boilers. At the boiler, it is reheated and turned to steam again and the cycle continues. The steam system is "closed." Only rarely does water need to be added.

A large amount of water is needed to keep the condenser cool, more than would be supplied by the water pipes of a city. Thermal-electric plants are built near lakes or rivers where the supply of water is unlimited. Cold water from the lake is pumped into the condenser. The water takes on heat from the steam pipes, and when it is pumped back into the lake, it may be 10°C warmer than the lake temperature.

1. Identify the following features of the coal-fired thermal-electric plant by the numbers in the diagram shown here: cool water from lake, warm water to lake; turbine, coal dust, coal, boiler, generator, pulverizer, hot steam from boiler, precipitator, hot water to boiler, and smokestack.

2. Describe the purpose of each of the following briefly: coal system, steam system, electrical system, cooling system.

3. Explain step by step how the heat energy contained in coal is converted into electrical energy for the transmission lines.

4. Tear off a few pieces of paper about fingernail size. Run a comb through your hair. Bring the comb slowly to the pieces of paper until they move. Hold the comb steady and rap it lightly with a pencil. Describe what happened. What part of the thermal-electric plant in the diagram uses the idea you just demonstrated?

Activity

## How Does a Steam Turbine Work?

The following will help you make a model turbine to be driven by steam from a kettle of boiling water. Study the instructions carefully, especially when you are ready to test your turbine in a jet of steam.

**MATERIALS** You will need a #18 cork, about 3 cm in diameter, a coat hanger, 8 straight pins, 2.5 cm long, 2 straight pins, 5 cm long, 4 strips of aluminum foil about 1.5 cm × 7 cm, 10 boiling stones, a bunsen burner, a florence flask, a 1-hole rubber stopper fitted with a bent glass tube, 2 cm of rubber tubing and a glass tubing nozzle, a pair of pliers, a 5-cm nail, a retort stand, wire gauze, a retort ring, a retort clamp, a pair of scissors, and a pair of safety goggles.

**PROCEDURE** Find the center of each face of the cork (use a pencil mark to help you) and push a 5-cm straight pin into the center of each end.

Using a pen, draw lines around the body of the cork 1 cm from each end. This will give you 2 lines on which to position the 8 2.5-cm pins.

Now push 4 pins into the cork at right angles to each other on the first line, as shown in the diagram.

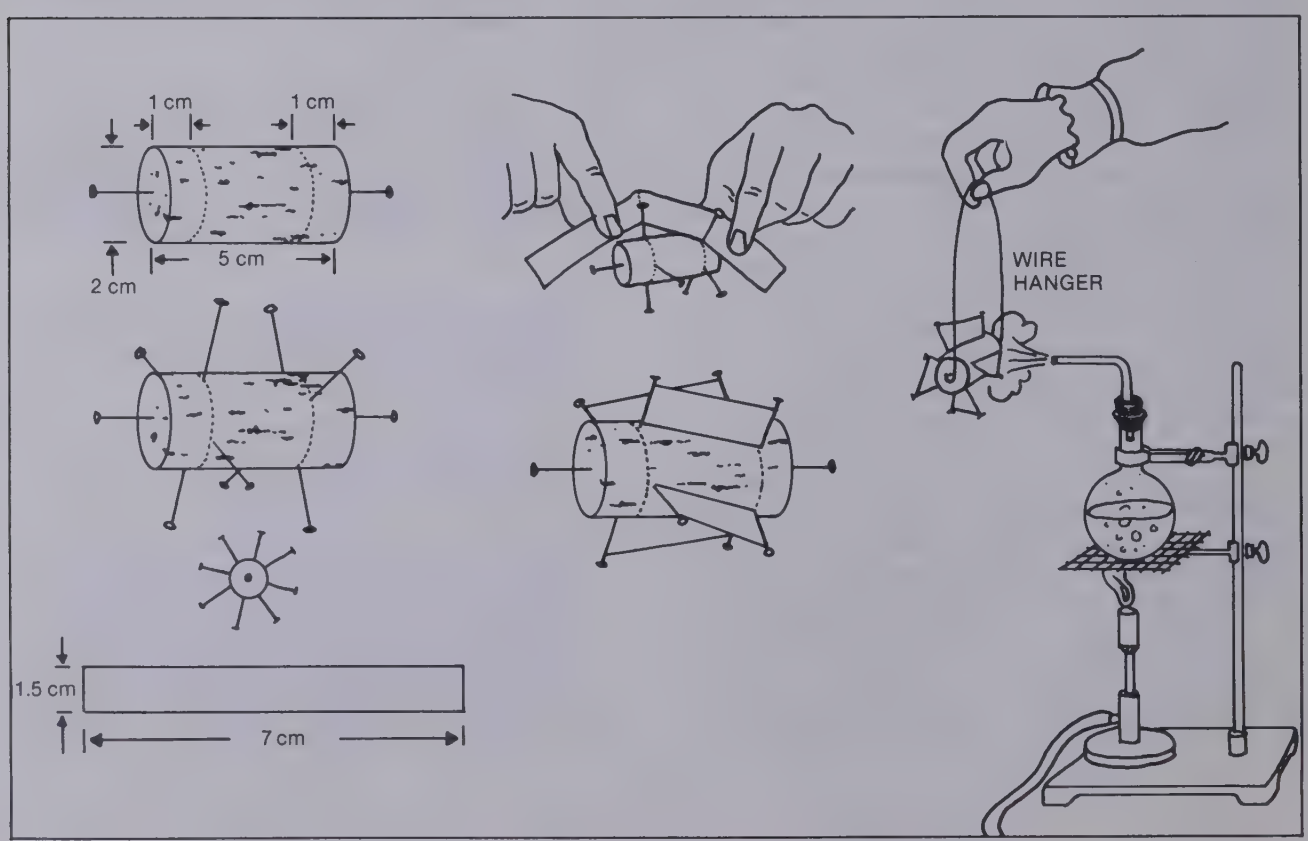
Along the second line, push 4 more pins into the cork at right angles to each other, but not in line with the first pins. Position them halfway between the first 4 pins. This will give your turbine blades some "pitch" (angle or twist). Leave about 1.5 cm of each pin sticking out of the cork.

With scissors, cut pieces of aluminum for your turbine blades. These should be about 1.5 cm wide and 7 cm long.

Wrap the foil around 2 pins to form each blade of the turbine. The foil will stay in place if pinched into shape and the ends are folded over. Keep the side of the turbine blade that the steam is going to strike as smooth as possible.

Bend 60 cm of coat-hanger wire and loop the ends to form a hanger on which the turbine can be mounted.

Now, you are ready to test your turbine. Set up



the steam generator, as shown in the diagram. Add 10 boiling stones to produce a smooth steady boil. *Do not heat too strongly.* One partner should maintain a watch on steam production and remove the heat if steam production is too rapid. If steam pressure gets too high, the rubber stopper should pop out. *Wear safety goggles and keep your fingers away from the nozzle. Stand up so that if any boiling water is spilled, you can step out of the way. Steam is much hotter than boiling water and can produce painful burns.* Lower the turbine into the steam until it spins well. Now you can try to improve your turbine. The following questions will guide you. To answer them you will have to experiment.

- Does changing the angle at which steam strikes the blade improve the turbine? (The higher the pitch of the sound, the faster the turbine is spinning, and the more energy it has.)
- Is the "velocity" of the steam important? You can increase the steam velocity by faster boiling (more power) or by decreasing the size of the opening from the steam generator. *Be careful! Never block the opening completely; steam has tremendous energy and can blow up the flask.* To produce a jet of higher velocity steam, attach the glass nozzle to the bent glass tube using the short section of rubber tubing. *Allow the steam generator to cool a little first.* How does the size of the opening in the nozzle affect the speed of the turbine?

*In cleaning up, remember that the retort ring is very hot.*

**OBSERVATION** What happened when you changed the angle at which the steam struck the turbine?

What happens when the water is boiled harder?

What happens when the size of the nozzle is reduced?

**CONCLUSION** Is the angle at which the steam strikes the turbine blade important? If so, what was the best angle?

Is the velocity of the steam important?

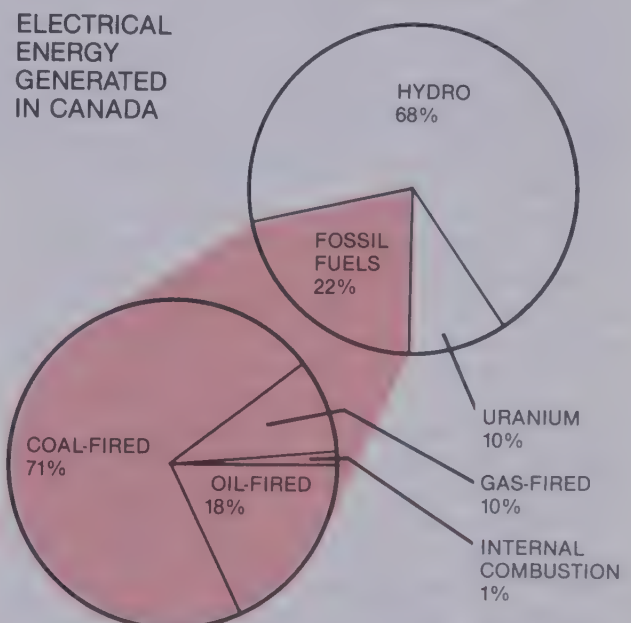
What two ways did you employ to increase the velocity of the steam?

**EXTENDED CONCLUSIONS** In spinning the cork, your turbine is converting the energy in the steam into the rotational energy of the turbine. How could you change your apparatus so that the energy in the turbine could be employed in doing useful work?

Can you think of a way to collect the steam that escapes and return it to the steam generator so that the steam could be used again?

### Advantages of the Fossil-fuel Thermal-electric System

Fossil-fuel thermal-electric plants have some important advantages over other methods of producing electricity. For one, the choice of location is more flexible. Although fossil-fuel thermal-electric plants can't be built just anywhere, it usually is possible to choose a site near the customers—the industries and homes in cities. A fossil-fuel thermal-electric plant means short transmission corridors—and low costs—to carry the electricity to the consumers. Another advantage of fossil-fuel thermal-electric plants is that they can operate on different fuels. Oil is a very expensive fuel, except in areas that have their own supply. However, natural gas can be used as fuel, and so can coal, which is often the cheapest of the fuels. (In a later section, you can read about the use of uranium as a thermal-plant fuel.)




1. Look at the first graph shown here. Why is the percentage of electrical energy from hydroelectric power not greater than 68%?
2. Look at the second graph. What changes would you expect to see in this graph over the next few years? Why?

## Disadvantages of the Fossil-fuel Thermal-electric System

**Costly fuels** The first price we have to pay for fossil-fuel thermal-generated electricity can be easily counted in dollars, because the fuel costs of a thermal-electric plant are high. Oil-fired thermal plants are becoming too costly and are being converted to natural gas or coal. Coal is a cheaper but less attractive fuel than petroleum in some ways. It is bulky, heavy, costly to move, and dirty. However, we have large quantites of coal in Canada and if coal fields occur where electrical energy is needed, coal will probably be the fuel used.

To produce 1000 MW (megawatts) of electricity, the amounts of fuel required each hour are 300 t of coal, or 250 $m^3$ (cubic metres) of oil, or 220 000 $m^3$ of natural gas. Prices for fuels will vary because of transportation costs.

**Polluting wastes** When coal burns, it leaves ashes. Almost all of the ash can be recovered, either as bottom ash in the firepit or as fly ash in the smokestack. The ashes present a disposal problem. The amount of coal burned in Canada in one year to produce electricity—9 Mt (megatonnes)—leaves about 1 Mt of ashes. So far, in this country, we have no plan for coping with the ashes except to bury them and landscape the disposal site. Something must be done with the ashes because they are a source of pollution. Rain that penetrates ash heaps or buried ashes will pollute streams or ground water. The disposal problem of coal ashes is a large one. It is estimated that a 1000-MW coal-fired station would produce enough ashes in forty years to cover an area 1 $km^2$ to a depth of "several tens of metres."

**Air pollution** The most serious problem created by fossil-fuel thermal-electric plants is air pollution. It is impossible to operate fossil-fuel thermal-electric plants without affecting the environment. The environment suffers the most from the harmful particles and gases released into the air by the burning of fossil fuels. Oil and natural gas contribute to air pollution, but coal is the worst offender. A 1000-MW plant, burning 300 t/h of coal would send these by-products, among others, into the air:

| | |
|---|---|
| sulfur dioxide | 14 t |
| nitrogen oxides | 2.2 t |
| particulates | 450 kg |

Sulfur dioxide and nitrogen oxides leave the tall smokestacks of fossil-fuel thermal-electric plants and drift across the sky. Eventually they combine with water vapor in the air to form acids that fall as acid rain or snow. These acids are weak solutions. Acid rain can't usually be told from rain (except for one rainfall in Scotland when the rain was found to be as acid as vinegar). The harm comes over a period of years, when the steady addition of tiny amounts of acid will kill off marine life in a lake. As the level of acid increases, the reproduction of fish, plants, and other marine life slows down and eventually stops. The result is a lake that is clear, beautiful, and dead. In Ontario, the province most affected by acid rain so far, over 140 lakes are "dead" and thousands more show acid rain effects.

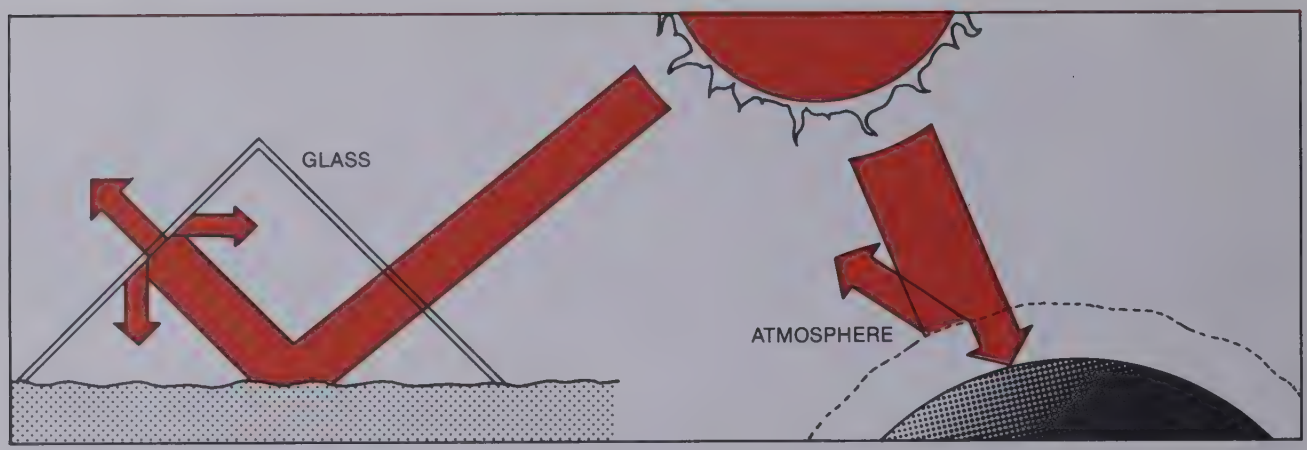
Other evidence of air pollution shows up in cropland. Farmers in some areas of southern Ontario have given up growing white beans, tobacco, and tomatoes because these plants are damaged by pollutants in the air.

Fossil-fuel thermal-electric plants are not the only sources of sulfur dioxide. While the burning of fossil fuels in furnaces, automobiles, and industry contributes most of the air pollution, coal-fired thermal-electric plants produce a

significant amount. Since fossil-fuel thermal-electric plants put their by-products high in the air with the help of tall smokestacks, wind direction has a great effect on where the acid rain comes down. Much of the pollution that comes down in the eastern part of Canada has its origin in the United States. From a recent announcement made by the United States, we know that the flow of acid-rain clouds will get worse. Because of the continuing increases in the price of oil, 80 fossil-fuel thermal-electric plants in the United States will convert from oil to coal.

What can be done about acid rain? There are only two answers at this time: treat the effects or remove the cause. "Treatment" means spreading crushed limestone on the lakes that show acid rain damage. Since limestone is expensive and the treatment is good for only one year and there are thousands of lakes, the idea does not seem practical. The other answer is to cut down on the amount of air pollution. We could do this in several ways. One is by spending millions of dollars to install "scrubbers" in the smokestacks of every coal-fired boiler to remove most of the sulfur dioxide. We could also reduce the amount of acid rain by reducing the amount of coal burned. In other words, by using less electricity.

Still other suggestions are to burn coal with a low sulfur content and to build taller smokestacks. Bituminous coal from western Canada has a lower sulfur content than coal imported from the United States. However, this western coal would be more expensive because of the long distance it must be hauled by freight train. Smokestacks could be built much taller than they are now. The effect would be to get the pollution higher into the air and for a longer time so that when it did come down the concentration would be decreased. Yet this would merely pass our acid-rain problem on to others.




**The "Greenhouse Effect"** In late winter, seeds can be planted in the soil of a greenhouse. Energy from the sun, in the form of light, comes through the glass and strikes the soil. The light energy is converted into heat energy. Most of the heat energy is trapped in the greenhouse by the glass and the greenhouse warms up. Even on cold winter days, the glass barrier will keep the heat in and the seeds will be warmed and will grow.

In a way, the whole earth is like a greenhouse. The atmosphere of the earth is the glass roof. Sunlight passes through the atmosphere and is converted into heat energy. Some of this heat energy is trapped on the earth, causing the "greenhouse effect" of the atmosphere. What is happening lately, according to some weather scientists, is that more heat is being trapped than usual because there is more carbon dioxide in the air. Carbon dioxide is a gas produced by the burning of fossil fuels. We have been burning so much fossil fuel that the increase of carbon dioxide in the atmosphere acts like a thicker blanket. More heat is being trapped than ever before and the earth is warming up.

Having a warmer earth with milder winters and long, hot summers might seem like a good idea. The consequences could be disastrous, however. If a warming of the globe took place, there would be shifts in the weather patterns. Areas that now grow food could be struck by drought. The entire web of food production and distribution would be upset.

Even more dramatic would be the melting of the ice caps at the poles. Immense quantities of water are now locked up in the ice that is kilometres thick at the north and south poles. If this ice were to melt, the level of the oceans would rise. Consider how much of the world's civilization is built near the sea and would be flooded with a rise in the oceans of only a few metres.

How much warmer would the earth have to be for the melting to begin? The experts are not sure, but a rise of just one degree in the average temperature of the globe could be dangerous.

1. How much does it cost to operate a fossil-fuel thermal-electric plant on each of the fossil fuels for 24 h? Assume that the plant produces the same amount of electricity each hour.
   If you can find accurate costs for your region, use them. If not, use these prices:
   coal $195/t
   oil 29.4 ¢/L
   gas 18.73 ¢/$m^3$
2. In a recent year, we had a generating capacity of 72 873 MW in Canada, and we depended on coal to produce 34% of this amount. About how many 1000-MW coal-fired generating stations were needed?
3. Choose one or more of the alternatives for coping with acid rain and try to make a convincing argument for your solution to the problem.
4. Geologists know that the earth went through a similar warming period many millions of years ago. Research to find out what the earth looked like then. Draw a map showing the areas of lakes and seas during this massive warming trend.
5. Many provinces and states have enacted legislation to reduce $CO_2$ pollution. Find statistics to discover whether or not this legislation has improved air quality.

## Thermal-electric Power from Uranium

Uranium is not a scarce element. It is found in small quantities in most rocks and soils as well as in the waters of our lakes and rivers. When the concentration of uranium in rock is greater than 1000 parts per million, the rock is considered to be uranium "ore" and may be worth mining. The largest known deposits of uranium ore in Canada are in northern Ontario and northern Saskatchewan.

The mining of uranium ore is accomplished by two major types of operations. When deposits are found near the surface, it is possible to use the cheaper and faster strip-mining procedure. Deeper deposits of ore have to be reached by the drilling and blasting technique used to make shafts and tunnels.

After the ore is recovered, it is broken up and crushed into 10-cm-size pieces. Then it is loaded with front-end loaders and hauled to the mill in large fleets of trucks. When the ore arrives at the mill, it is crushed and ground until it becomes a fine sand.

The next step in the processing of uranium ore is the addition of chemicals to the sand.

The muddy liquid is then neutralized and the uranium-rich solution is separated from the solid particles or mud. To get the uranium out of the liquid, a chemical is usually added that absorbs the uranium from the solution. The mixture containing the uranium is then filtered out, dried, and packaged for shipment from the mill.

The uranium concentrate, now called $U_3O_8$, or yellowcake, is refined to remove impurities. It is then made into hard, glassy pellets about 1.5 cm in diameter and 2 cm long. These pellets are used as reactor fuel.

Our most recently used nonrenewable source of energy, uranium, is very different from the fossil fuels. Coal, oil, and natural gas are burned to release heat energy; uranium is the fuel for a process called fission—a reaction that produces intense heat. The heat of the nuclear reaction is harnessed to a turbine and electrical generator, similar to other thermal-electric generating plants mentioned earlier.

An atom can produce electricity. The atom we are particularly interested in is an atom of uranium. Uranium is the heaviest element known to us. Its atoms are heavy and unstable, that is, they break apart easily. When the nucleus of an atom breaks apart, nuclear energy is released. When an atom of uranium splits, its nucleus breaks, spills some neutrons, and then forms itself into the nucleus of another atom. The spilled neutrons go flying off at about 42 000 km/s. If these neutrons are slowed down, they can be used to split other atoms of uranium which, in turn, spill more neutrons and cause more atoms to split —this is a chain reaction.

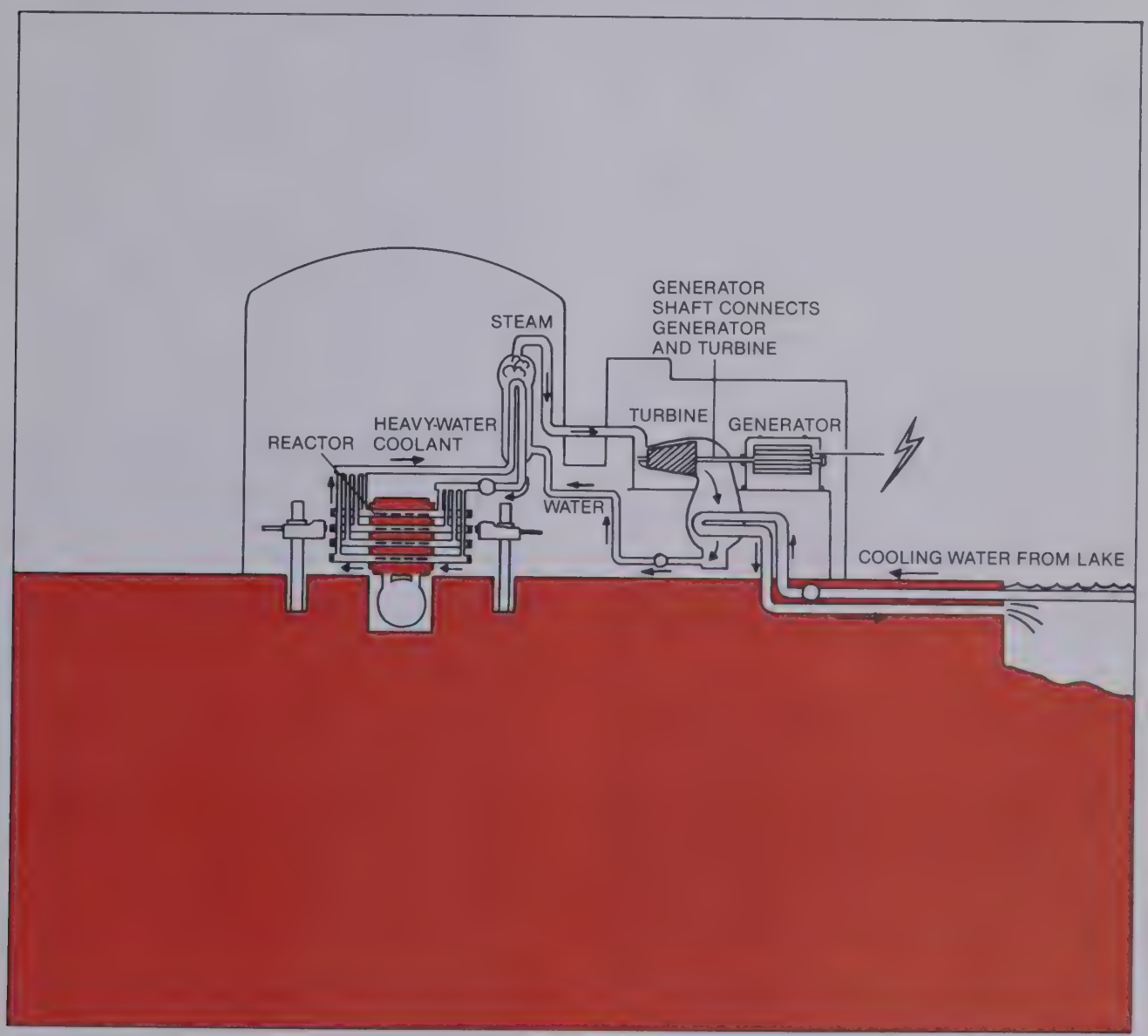
A chain reaction occurs when one event causes several other events to happen in succession. For example, you may sit down at the table for breakfast and accidently bump your plate, which slides across the table, hits the ketchup bottle which topples over and hits a glass of milk which spills into your cereal bowl. Note that this reaction may not work the same way every time. This is called an uncontrolled chain reaction.

A nuclear reactor is designed to promote an atomic chain reaction in uranium and to remove the heat produced in the fuel. So in many ways, a reactor is just a furnace that "burns" uranium in a different way. The heat it produces can be used for the same purpose as is the heat from burning wood, coal, oil, or natural gas.

Thus, an atom of uranium, by splitting or "fissioning," can produce heat to produce steam to make electricity.

Although both fossil fuels and uranium are nonrenewable, it is easy to understand the interest in nuclear energy when we consider that heat from fission of a 1-kg fuel bundle equals approximately the heat from the burning of 400 Mg (megagrams) of coal or 1700 barrels of oil.

Canadian or CANDU (Canada-deuterium-uranium) power reactors use natural uranium as fuel. The uranium pellets, which resemble large pills, are loaded into thin tubes of metal alloy. The tubes are then closed at the ends and the sealed tubes made into bundles. Each bundle has a mass of about 23 kg and produces energy equal to that provided by 400 Mg of coal. A large reactor may have three or four hundred fuel channels into which these fuel bundles can be loaded.




*In the diagram shown here, you will notice that the turbine-generator part of an atomic plant is the same as an ordinary thermal-electric plant, and the product is identical—electricity.*

Also needed in the reactor is heavy water. This is a combination of a heavy form of hydrogen and oxygen. Ordinary water, which is "light" water, and heavy water look and feel alike. However, heavy water is especially effective in slowing or moderating the nuclear reaction.

When the fuel is surrounded by the heavy-water moderator, a chain reaction of atom splitting is set up. This causes the fuel inside the tubes of the reactor to become hot. This heat is transferred by the heavy water to the steam generator which produces steam. The steam turns the turbines and the generator. The generator produces electricity.

After giving up its energy in driving the turbines, the steam is converted back into water in a condenser cooled by river, lake, or sea water and returned to the steam generator.

A large amount of water is needed to cool the condensers but this is kept separate from the water in the steam generator. A river or lake is usually used to supply the cooling water. Because the water takes on heat from the condenser, it is released slowly to the river or lake to keep the temperature from rising more than 10°C in the river or lake.

1. Compare the making of electricity with coal as a fuel with the making of electricity with uranium as fuel. You might like to use a chart similar to this one.

| ORE | COAL | URANIUM |
|---|---|---|
| MINING | | |
| REFINING | | |
| PROCESSING | | |
| FORM OF FUEL | | |
| TYPE OF FURNACE | | |
| USE OF HEAT | | |

2. Why do some people consider uranium to be the fuel of the future?

## Advantages of the Nuclear-electric System

**Fuel savings** Nuclear plants use less petroleum. There are important uses for petroleum, such as fuel for vehicles and aircraft, and feedstock for the petrochemical industries that cannot be met by other sources at this time. Some petroleum in the form of oil and gas is being used to heat homes and buildings. If these oil furnaces were changed to electric heat, the electricity needed could be provided by CANDU reactors, and less petroleum would be needed.

**Flexible location** Nuclear plants can provide electricity anywhere. Some parts of the country do not have hydro sites nearby, and they are a long way from cheap supplies of coal. Areas like this can still provide the electricity they need with a CANDU reactor, if there is enough water nearby to provide cooling. In Canada, you can usually find a source of water for cooling the condenser.

**Absence of acid-rain effects** Nuclear-electric plants do not create acid rain. Canadian citizens are urged to practice conservation of energy. If the conservation goals are not met, new thermal-electric plants will be built to supply the electrical energy. The choice of fuels will usually be coal or uranium. If coal is the fuel, we must be prepared for the effects of acid rain. There are no acid rain effects with a CANDU reactor.

## Disadvantages of the Nuclear-electric System

**Nuclear waste** Nuclear generating plants create radioactive waste. The familiar materials of our world don't change, or if they do, the change is very slow. Brick walls and wooden floors are stable, and we expect them to be the same tomorrow as they are today. There are some materials in the world, such as uranium, that are not stable. They can change to entirely different substances. Such unstable elements try to become stable by getting rid of the extra energy in their nucleus. They do this by allowing particles to escape at high speed, or by sending out energy that is very similar to that produced by an X-ray machine. Unstable elements that release either of these kinds of energy are called radioactive and the energy they release is referred to as radioactivity.

There are radioactive elements on earth today that were created when the earth was formed. Others are formed each day in the atmosphere by

natural processes we cannot change or stop. Others are produced by people. No matter how they are produced, radioactive materials are all unstable and change into different elements. The energy they release in doing so can be harmful, but it also can be used for our benefit.

When the change or decay of uranium is complete, it is no longer radioactive, and in fact is no longer uranium. It is lead. This process of decay is measured by "half-lives." A half-life is the time it takes one half of the atoms to decay and change into another element. Uranium has a half-life of four and a half billion years. This means that uranium decays very slowly and that only a few of the huge number of atoms in uranium are giving off particles.

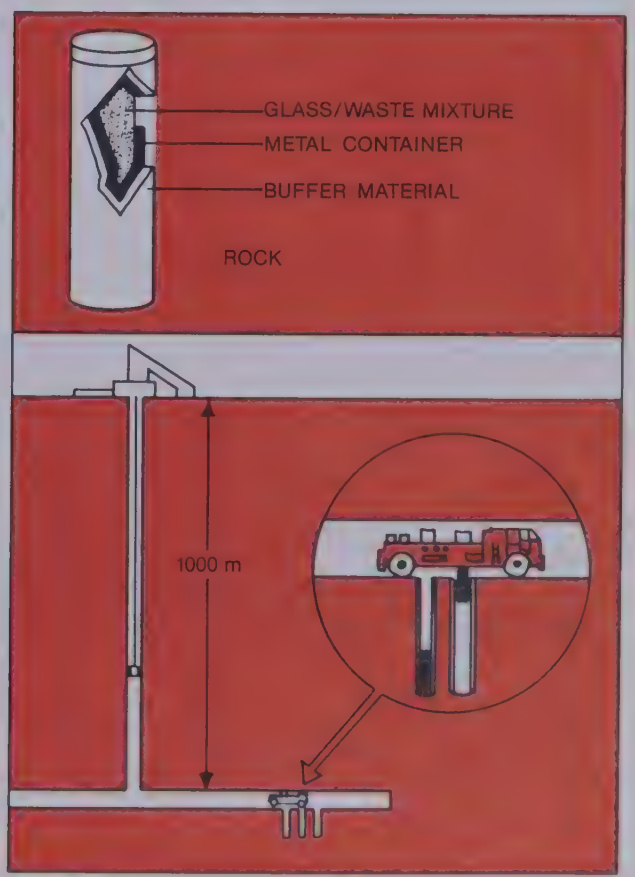
Other elements are more radioactive than uranium. More of their atoms give off particles at a much greater rate. Radium, for example, has a half-life of sixteen hundred and twenty years. Radium is a very scarce element because it decays so quickly.

Whenever a nuclear power plant operates it produces some radioactive wastes. These wastes are materials for which there is no use at present.

Most of these wastes are in the form of spent fuel. This is fuel that has been only partially used up but has been replaced because it can no longer operate the reactor economically. This spent fuel is highly radioactive and must be handled very carefully. Waste management refers to all actions taken to ensure that radioactive wastes remain under control until they are no longer a hazard to people or their environment.

Storage means placing the wastes in a container or special structure with the intention of retrieving them in the future. At the present time, all spent fuels are stored in water-filled pools at the nuclear-power stations. While these pools will remain in use, most experts are also recommending other types of storage facilities.

The idea that has received most attention is that of burying these wastes deep in the ground. Geologists know of some salt deposits or hard-rock formations that seem to have remained stable for



hundreds of millions of years. It is claimed that if nuclear wastes were buried deep in these formations, it is unlikely that they could escape and be harmful to present or future generations.

Disposal means placing the wastes with no intention of retrieving them. No feasible suggestions for disposal have yet been made.

Before uranium can be used to power nuclear-electric plants, it must be mined. Only a small amount of the rock taken from the mine contains uranium. About 1 t of waste is left for each kilogram of yellowcake produced. The discarded tailings contain both radioactive materials and harmful chemicals left from the separation process. Disposal of the tailings is another unsolved problem.

**Health hazards for workers** The miners who work in the underground mine are exposed to radon gas, one of the by-products of radioactivity. Tiny particles can be inhaled. Good ventilation in the mine helps to protect the miners. But uranium miners still run much higher risks of lung cancer than do other people.

Are nuclear reactors safe? The argument over this question goes on. Those in favor of reactors point out that there has never been a fatal accident with a CANDU reactor. The CANDU has as many safeguards built in, it is claimed, as engineers can devise.

Opponents of nuclear reactors point out that everything built by human beings breaks down some time because human beings aren't perfect. A breakdown in a CANDU could be a disaster. The risk is not worth it, say the opponents.

**Costly construction and maintenance** Nuclear reactors are expensive to build and maintain. After twenty-five or thirty years, the reactor is expected to have reached the end of its life and may have to be "decommissioned." This is the reverse of the building program and is costly. However, when compared to the income generated over the lifetime of the plant, the cost of decommissioning should be acceptable.

1. Explain what is meant by the term *waste management*.
2. Explain how *storage* differs from *disposal*.
3. Is the risk to miners in mining uranium the price we must pay for energy?
4. Can a Three Mile Island disaster happen with a CANDU reactor? Do research to find out.

# 5

# Using Electricity from Hydro Resources and Thermal Energy

Electricity has been called our most useful form of energy. Electricity touches every part of our lives. Look around you and try to find something that has not required electricity in its manufacture. It is unlikely you will be able to find even one item, yet we take electricity almost completely for granted. At any time, we expect to turn to those outlets on the wall for an endless supply of useful energy. So far, we haven't been disappointed.

## Life Before Electricity

The convenience of electricity is fairly recent. Even now, you will be able to talk to adults who can tell you what life was like before electricity was available to everyone. If we go back a little further, say about one hundred years ago, life in Canada was quite different from life in Canada today.

One hundred years ago, some Canadian cities had street lamps that burned coal gas. Candles and kerosene lamps provided light at home. For safety, the lamps were blown out at bedtime—nights in the city were dark.

Stoves fueled with coal or wood provided heat for both warmth and cooking. Imagine what it was like to cook a big family meal on a hot day in July.

Food was kept in a wooden chest called an icebox. In hot weather, the horse-drawn ice wagon delivered blocks of ice to homes two or three times a week. An icebox kept food cool, not cold.

Clothes were washed by hand in wooden or metal tubs. Hard-to-clean clothes were rubbed on a scrubbing board, a board with a rippled surface. After rinsing, the clean clothes were hung to dry inside the house on rainy days, or on the clothesline on fine days. In winter, clothes often froze before they dried.

Ironing made use of several irons. A detachable wooden handle fit all the irons. While one iron was being used, other irons would be set on the stove to heat. When the first iron cooled, it would be placed on the stove and the handle attached to a hot iron.

Hand-powered tools like the broom, mop, scrubbing brush, and carpet beater kept the house clean, if someone could be found to operate them.

Coal-burning locomotives travelled between a few of the settled areas of the country. Most transportation depended on the horse. Horses pulled wagons, sleighs, buggies, and street cars.

The early water-powered mills were still operating. Some more modern factories had machinery powered by coal-fired steam engines.

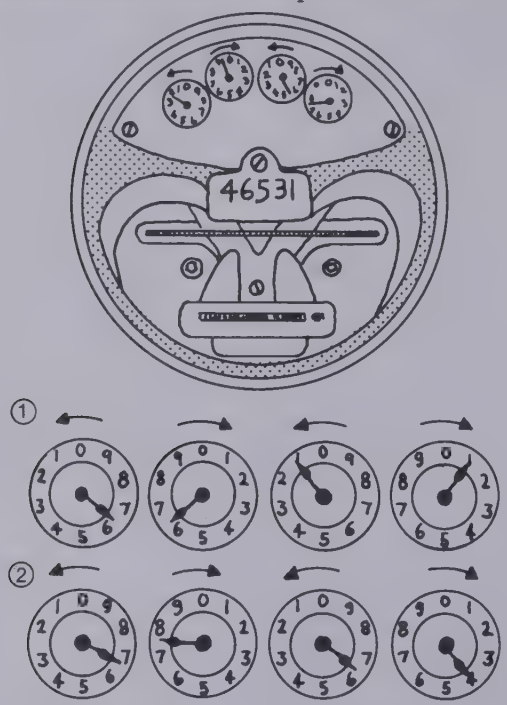
Telegraph wires were strung on poles between cities and news travelled along the wires in a dot-and-dash code. The news was printed on hand-operated or steam-driven newspaper presses. Outside the cities, news travelled slowly by steamship, by courier on horseback, by foot. The fastest route to the West at this time was the canoe route of the voyageurs.

1. Which of the tools and machines mentioned are still with us?
2. List the tools and machines mentioned that have been replaced. What has replaced each one?
3. What form of energy operates each of the new tools or machines?

## How We Measure the Electricity We Use

Today, the power company that brings electricity to a house, apartment building, or a factory also provides a meter to measure how much is used. The meter records how many watts of power are used over a period of time. At regular intervals, a power company employee comes to read a customer's meter. The power company calculates the amount of electricity used and charges the customer for it.

The watt is a small unit, so the basic unit used by the power company is 1000 W, the kilowatt (kW). Since lights and appliances are constantly turned on and off, the electricity we use is measured over periods of one hour and the unit is called one kilowatt hour (kW·h). A kilowatt hour means one thousand watts used for a period of one hour.




*The face of a meter may have dials, like this. The pointers are linked together by gears. Some pointers turn clockwise and some turn counter-clockwise. When the pointer is between two numbers, read the smaller number. The reading on meter ① is 66 100 kW·h. Meters with four dials, as shown here, have the instruction "Multiply by 10." (Some meters have five dials. When you read these meters you do not multiply by 10.)*

Charges for electricity vary from place to place, but the pattern for the rate structure is much the same. Here is a typical residential service rate.

| RATE CARD 1 |
|---|
| First 50 kW·h–4.6¢ per kilowatt hour |
| Next 200 kW·h–2.3¢ per kilowatt hour |
| Next 750 kW·h–1.7¢ per kilowatt hour |
| Additional Service–$3.50 per month |

Note that the charge is highest for the first 50 kW·h. The more electricity you use, the lower is the rate for each kilowatt hour.

1. The diagram of meter ② shows the meter ① one month later. What is the reading now? How many kilowatt hours of electrical energy were used during the month?
2. Using Rate Card 1, calculate the charges for meter ②.
3. What is the average rate on the typical bill at the bottom of this page? Compare this rate with Rate Card 1.

| RATE CARD 2 |
|---|
| Residential Service Rate |
| 2.8¢ per kilowatt hour |

4. Which rate encourages homeowners to use more electricity—Rate Card 1 or Rate Card 2?
5. If you burn a 100-W bulb for one hour, how many kilowatt hours of electricity will you use?
6. If you burn the same 100-W bulb for 10 h, how many kilowatt hours of electricity will you use?

| present reading | reading date | meter number | | $ | ¢ |
|---|---|---|---|---|---|
| 606 | OCT 27 | H608087 | | | |
| previous reading | days since last reading | average kW·h used per day | ENERGY CHARGE | 129 | 40 |
| 314 | 83 | 35 | | | |
| reading difference | multiplier | energy used kW·h | | | |
| 292 X | 10 = | 2920 | | | |
| | | | PAYMENT DUE BY DEC 02 | 129 | 40 |

*Here is a typical bill from an electric power company. You can calculate the average charge for a kilowatt hour by dividing the total charges, expressed in cents, by the total number of kilowatt hours.*

## How We Use Electricity
## Household Appliances

The amount of electricity used for electrical appliances (things that use electricity, such as toasters, radios, and so on) depends on two factors. One is the length of time they are used. The other factor is the amount of electricity required to make each appliance operate. These two factors determine the electrical energy we use each month. The meter keeps a record of the total electrical energy used, but does not tell us about individual appliances.

The table on this page lists some appliances, the wattage for each, and an estimate of the time each is in use for one month. To calculate how much energy any appliance converts, express the energy in kilowatts and the time in hours. For example, a clothes dryer is used for one and a half hours. From the table, a clothes dryer uses 4800 W or 4.8 kW.

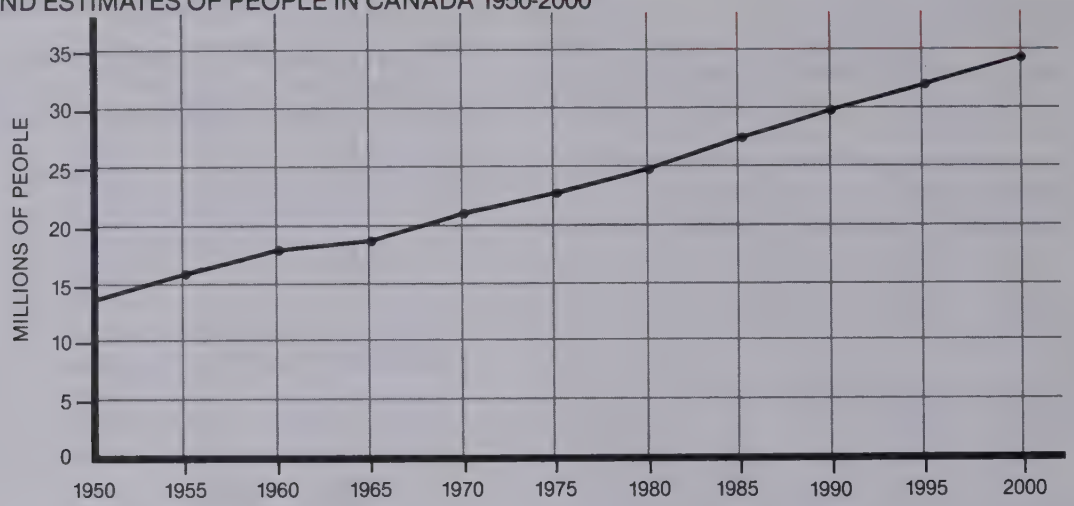
Energy used in 1.5 h is $4.8 \times 1.5 = 7.2$ kW·h

1. What are the two biggest converters of energy in the home?
2. What is the average monthly cost of using a freezer? (To find the cost of operating one of the appliances listed, use 3.8 ¢/kW·h as an average rate.)
3. Suppose each household was limited to owning just five appliances. List the five you would choose in order of importance.
4. Refer to the list of electrical appliances in your own home. Choose three and calculate the energy converted and the cost for one year.
5. How much does it cost for one year to use electrical appliances to wash, dry, and iron your clothes? (Hot water for clothes washing uses about one-third of the water heated in an average household.)

**Power Rating of Electrical Appliances and Average Monthly Use**

| Appliance | Power Rating (W) | Time (h) | Appliance | Power Rating (W) | Time (h) |
|---|---|---|---|---|---|
| Air conditioner | 935 | 65 to 425 | Kettle | 1 500 | 8 |
| Blanket | 180 | 55 | Lawn mower | 1 500 | 2 |
| Block heater | 500 | 90 | Lighting | | |
| Can opener | 175 | 2 | Table lamp | 100 | 80 |
| Clock | 2 | 744 | 5-bulb fixture | 300 | 30 |
| Clothes dryer | 4 800 | 17 | Ceiling fixture | 60 | 35 |
| Coffee maker | 900 | 7 | Oil burner | 260 | 200 |
| Deep-fat fryer | 1 500 | 4 | Radio | 5 | 200 |
| Dehumidifier | 350 | 45 | Range, standard | 12 500 | 8 |
| Dishwasher | 1 300 | 14 | Refrigerator, frost-free | 500 | 300 |
| Floor polisher | 300 | 4 | Sun lamp | 280 | 4 |
| Food-waste disposer | 450 | 6 | Toaster | 1 150 | 3 |
| Freezer | 425 | 200 | TV, black-and-white | 200 | 150 |
| Frying pan | 1 150 | 14 | TV, color | 330 | 125 |
| Furnace fan | 250 | 400 | Vacuum cleaner | 800 | 6 |
| Hair dryer | 350 | 9 | Waffle iron | 1 120 | 2 |
| Hi-fi | 30 | 200 | Washing machine, automatic | 500 | 16 |
| Humidifier | 100 | 100 | Water heater | 4 500 | 115 |
| Iron | 1 000 | 12 | | | |

RECORDS AND ESTIMATES OF PEOPLE IN CANADA 1950-2000




## Going Up!

In Canada in 1976, we were able to produce 59 540 MW (megawatts) of electricity. For the twenty-five years before 1975, our demand for electricity had increased by 7% each year.

1. At the 7% rate of increase, how long do you think it would take for the demand for electricity to double? That is, beginning with 59 540 MW, how many years would pass before the demand was about 120 000 MW? Make a guess. Then complete this exercise with the help of a pocket calculator.
   *a.* Make a table like the one here. This table will be your record of the number of megawatts for each year as demand increases by 7%.
   *b.*

| Increase per Year (7%) | |
|---|---|
| Year | MW |
| 1976 | 59 540 |
| 1977 | 63 707 |
| 1978 | 68 167 |

   *c.* Enter 59 540 on your calculator. Multiply by 1.07 and record the whole number 63 707 for 1977.
   *d.* Do not erase the number. Multiply it by 1.07 and record the whole number 68 167 for 1978.
   *e.* About how many years does it take a number to double if the number is increased by 7% a year?
   *f.* Make a prediction. At the same 7% rate of increase, about how many megawatts of power will be demanded by the year 2000?
2. Make a line graph to show the demand for electricity for the years 1976 to 2000.
   *a.* About how many times more electricity will be demanded in the year 2000 than was available in 1976?
   *b.* It should be clear that the 7% increase many people are used to cannot continue forever without many changes in capacity to produce electricity. Conservation practices, plus slow growth in the economy of the country, have slowed the rate of increase in the past few years to just over 4%. Graph the 4%-demand curve.
   *c.* How many years does it take for the demand for electricity to double at the 4% rate of increase?
3. In order to conserve fossil fuels, oil in particular, it has been suggested that residential and commercial buildings should be heated by electricity. Comment on the suggestion.
4. Study the Records and Estimates of Population graph.
   *a.* Is the growth pattern a steady one?
   *b.* What would you predict for the population of Canada in the year 2020?
   *c.* What is the increase expected over fifty years from 1950 to 2000?
   *d.* What is the average increase in population per year?
   *e.* What are the likely effects of this population increase on demands for electric power?

THEN

## A cent well spent

Two loads done already, and my automatic electric washer still has another twenty minutes to go before it uses up one cent's worth of electricity.

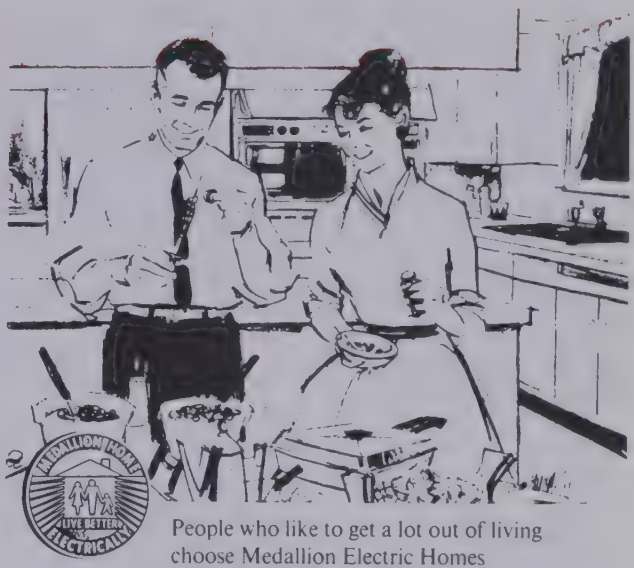
That's the kind of economy you get when you live electrically! In fact, electricity is so economical that you can run a whole houseful of electric appliances for only a few cents a day.

You get more out of life when you get the most out of electricity.

**live better... ELECTRICALLY**

*the safe, clean, modern way!*

YOUR LOCAL HYDRO




People who like to get a lot out of living choose Medallion Electric Homes

When you are buying a new home, insist upon a Medallion Home for assurance of the utmost in electrical living. This Medallion standard of electrical excellence enhances and protects your home investment.

FULL HOUSEPOWER AND APPLIANCE CONDITIONING guarantees all the power you need, where and when you need it, for all the wonderful electric appliances you will want to use now and in the future.

A feature in every Medallion Home is a modern, fast-recovery, flameless water heater, assuring all the hot water any family requires, and at the lowest possible cost.

LIGHT CONDITIONING provides the most desirable illumination both indoors and out, for work, for play, comfort, safety and beauty.

ELECTRIC HEATING — a feature in *Gold* Medallion Homes, provides the ultimate in safe, clean, silent heating comfort . . . with individual room-by-room temperature control.

DON'T BUILD OR BUY until you find out more about Medallion Homes . . . Speak to your local Hydro, Electrical Contractor, or Builder.

**HYDRO Is yours**

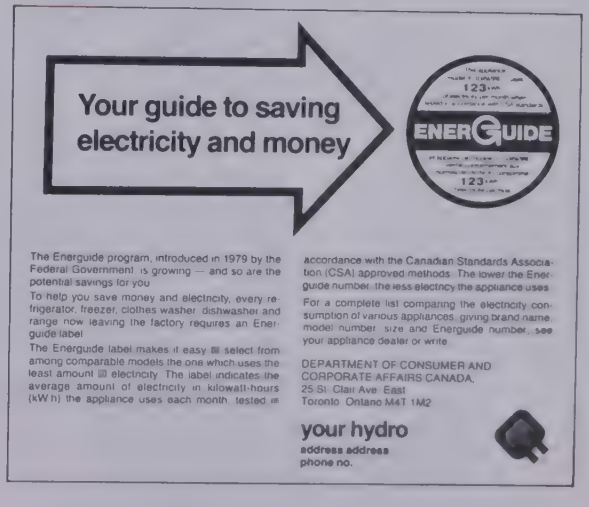
## Can We Conserve Electricity?

Electricity is a wonderful tool. It will run motors, provide light, and produce heat.

Electricity is not a natural resource. It is difficult to store large amounts until wanted. For large-scale use, it must be manufactured when needed by a process that converts natural resources.

Some of these advertisements are not very old. They were part of an effort to sell more electricity to consumers. They stressed convenience and comfort and "the good life." Many people—perhaps most people—have ideas about electricity today that belong in this period. They take for granted that every electrical appliance they want can be bought and used in their home. Yet the advertisements these days from the electric-power companies do not encourage us to buy more electricity—they stress *saving* it. What has happened?

NOW



**Your guide to saving electricity and money**

ENERGUIDE

The Energuide program, introduced in 1979 by the Federal Government is growing — and so are the potential savings for you.

To help you save money and electricity, every refrigerator, freezer, clothes washer, dishwasher and range now leaving the factory requires an Energuide label.

The Energuide label makes it easy to select from among comparable models the one which uses the least amount of electricity. The label indicates the average amount of electricity in kilowatt-hours (kW·h) the appliance uses each month, tested in accordance with the Canadian Standards Association (CSA) approved methods. The lower the Energuide number, the less electricity the appliance uses.

For a complete list comparing the electricity consumption of various appliances, giving brand name, model number, size and Energuide number, see your appliance dealer or write:

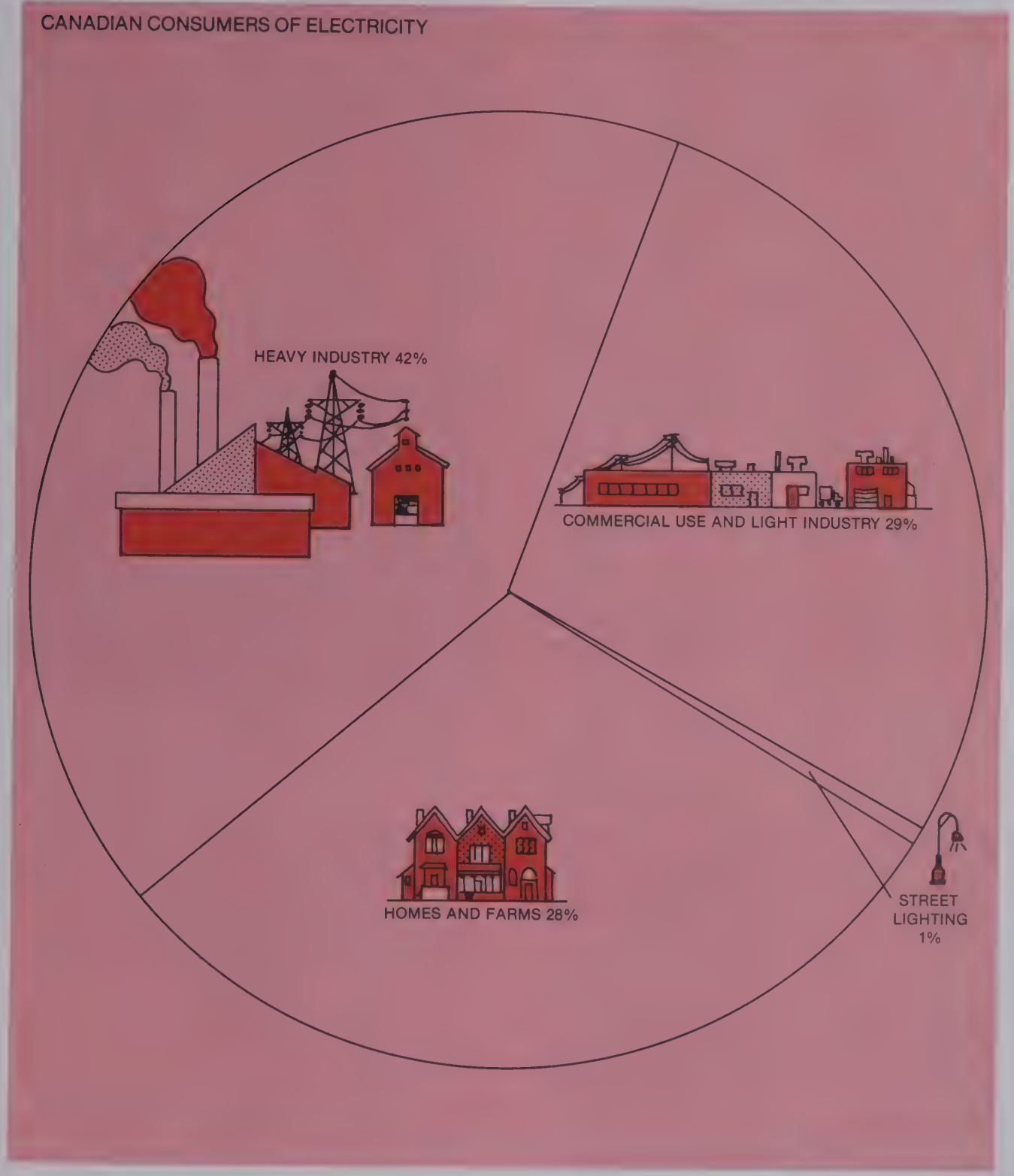
DEPARTMENT OF CONSUMER AND CORPORATE AFFAIRS CANADA,
25 St. Clair Ave. East
Toronto, Ontario M4T 1M2

**your hydro**
address address
phone no.

One reason we are not being "sold" electricity today is that we now have too many people making too many demands for electric power. Sometimes this has serious results. On November 9, 1965, the power supply failed during the evening rush hour in parts of Ontario, Quebec, nine American states, and New York city. With no warning of any kind, 800 000 people were trapped in the New York city subway. Traffic lights in dozens of cities stopped working. Landing lights and radar suddenly failed at airports. Thirty million people were without light and, in some cases, without heat. It took twelve hours to restore service in the system.

This has been our only experience with a blackout where a large part of the electrical-distribution system has failed without warning. However, some areas of the country experience the occasional brownout when the amount of electric power decreases enough to make bulbs dim and motors run slowly. The message is clear: we are close to having too many people make too many demands on the supply of electric power.

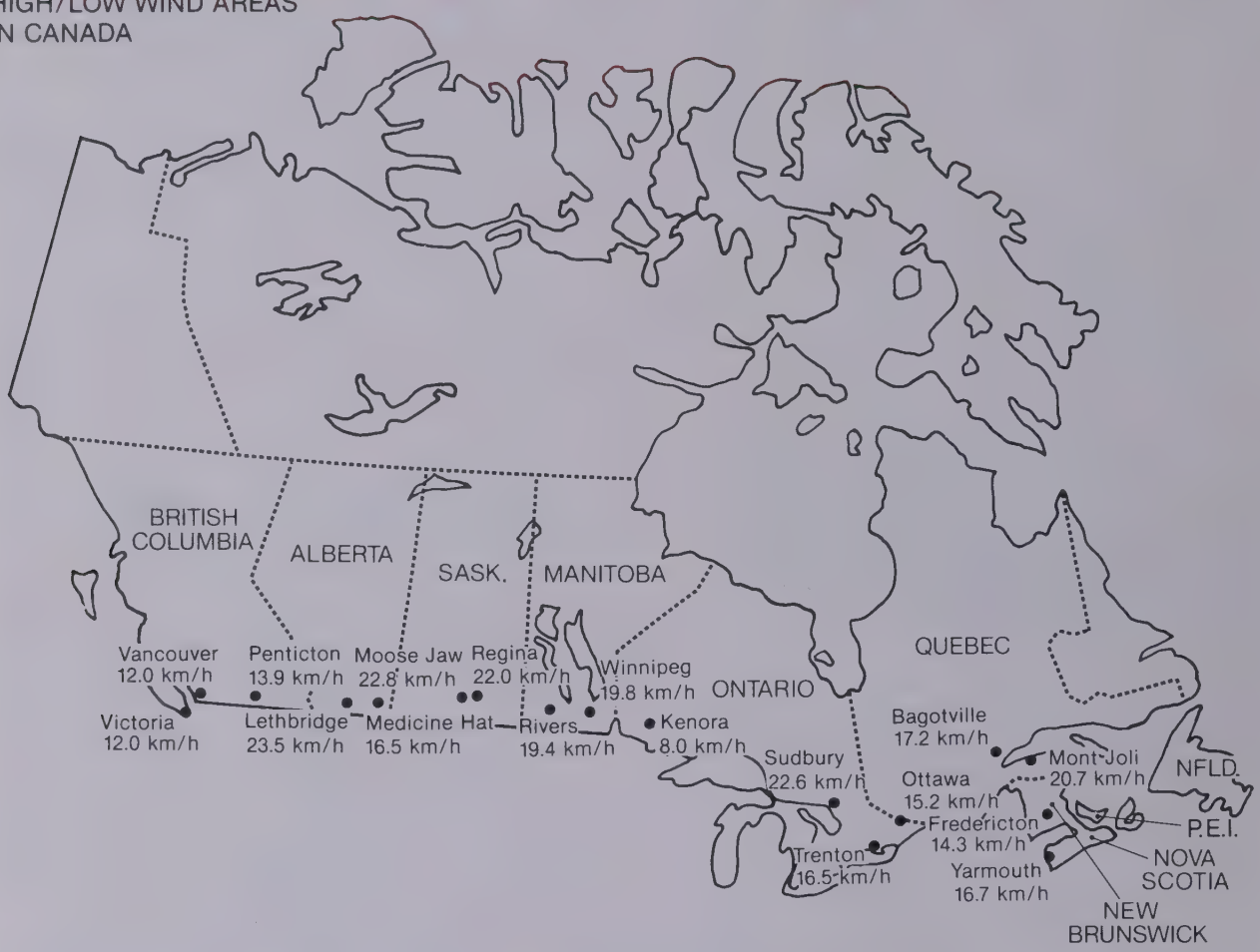
1. Look at the graph, Canadian Consumers of Electricity. The rate structures set by the power companies charge heavy users of electric power at a low rate, while those who use only a small amount of power pay at a higher rate. What effect do you think reversal of this rate structure would have? Be sure you comment on the effects on both light users and heavy users of electric power.
2. Some manufacturers are attaching labels to their appliances that tell the consumer how much power the appliance will convert. Should manufacturers be forced to use these labels? Would consumers refuse to buy appliances that were not efficient?
3. What fuel do you think home builders and home buyers should be encouraged to use — gas, oil, or electricity? Why?
4. Should home designers and home builders be required to design buildings that make the best use of the heat and light of the sun? Support your answer?
5. All thermal-electric plants create "waste" heat that must be disposed of. Should we try to capture this heat for some useful purpose? For what purpose?
6. One way to reduce our demand for electricity is to reduce the number of electrical appliances we use. Look back at the list of appliances we use. Look back at the list of appliances in your home. How many of them are you prepared to do without for a period of time, say three months?
7. Examine your list of *Needs* appliances. Try to think of some way of reducing the time each one is used without making life miserable in your home. Try your ideas for the same three-month period.
8. "More people means more demand for electric power. Therefore, we should compel people to have fewer children." Is this possible? One could argue that when families are smaller, they have more money for recreation and luxuries and so use more electricity, not less. What is your opinion?


CANADIAN CONSUMERS OF ELECTRICITY
HEAVY INDUSTRY 42%
COMMERCIAL USE AND LIGHT INDUSTRY 29%
HOMES AND FARMS 28%
STREET LIGHTING 1%

# 6

# Investigating Other Ways of Producing Electricity

HIGH/LOW WIND AREAS
IN CANADA




Other ways of generating electricity are constantly being investigated and promising sources developed. Some of these are practical now; others will require changes in technology and attitudes.

### Electricity from Wind Power

Wind power must be one of the oldest sources of energy that has been harnessed for work. For many centuries, wind has been turning wheels to grind grain and pump water. Now wind is being looked at again, this time as a source of energy to spin generators.

Wind-powered generators are not new. When electrical power was produced many years ago at the first hydroelectric station, it was first sold to the cities where the number of customers is high and the costs of putting in wires is therefore low. People in the rural areas were the last to get electrical service. It is expensive to string transmission wires on poles along country roads when there is only one customer every kilometre or so.

While they waited for the wires to reach them, many rural people made their own electricity. A small generator with a propeller attached was mounted on top of a tower. When the wind blew, the propeller turned and produced electricity for lights in the farm house and barn.

The wind is one source of energy that is free. Unfortunately, it is also unreliable. If one intends to use the wind to produce electricity, some method is needed to store the electricity for the quiet times when the wind is not blowing. Usually a number of batteries are wired together and electricity is stored in them during times of high wind. On windless days, the batteries provide electrical power for the farm house or barn.

A battery produces direct-current (DC) electricity which flows in a steady stream, something like a stream of water. Electricity can also be generated in pulses that change direction, or alternate, many times each second. This is called alternating current (AC). Alternating current cannot be stored in batteries, so the generator in a wind system must be a direct-current generator. Although lightbulbs will work on either AC or DC, electric motors must be wired for one or the other. Electric motors and appliances which are made in Canada are wired to operate on AC, and must be re-wired to use wind-generated electricity.

Although alternating current cannot be stored in batteries, it has one major advantage over direct current—it can be sent much longer distances over transmission wires. For this reason the electricity produced in hydroelectric-generating plants is alternating current, and all home appliances are manufactured to use alternating current.

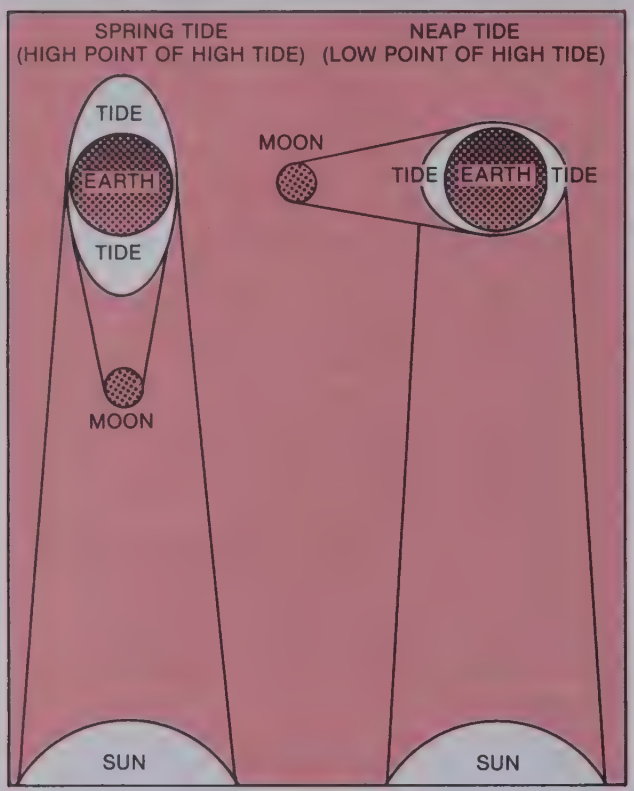
Years ago, farmers who had wind generators had to make a choice when electric power lines arrived, between retaining their wind generators or hooking up with the new system. If they chose to hook up to the alternating current supplied by the power lines, they had to discard their wind generators and batteries, and replace all the electric motors around the farm.

Today, the equipment for wind generators of electricity has improved. If one is very sure of a steady supply of wind where one lives, a wind alternator can be used, which will produce the alternating current needed for appliances. If one lives where the wind is not always blowing, a wind generator is needed to produce direct current for storage batteries. An inverter is also needed to convert the direct current into alternating current, so that regular electric appliances can be used.

The wind will be blowing for as long as the sun continues to shine on the earth and the thought of all the unused wind energy is a challenge to inventors. New designs for propellers continue to be developed. However, if wind generators are to become a major source of electrical energy, they will have to be of a great size and there will have to be a lot of them. To avoid the sight of a forest of towers supporting whirling blades, it has been suggested that the wind generators could be mounted on structures similar to oil-drilling rigs and floated offshore where they would be out of sight and where the wind is reliable.

1. Considering that small-scale wind-powered generating plants are available now, would you suggest using wind-powered generators? Where would wind-powered generators likely be disappointing?
2. What future do you see for wind-powered generators? Explain your answer.

## Electricity from Tidal Power



The force that attracts a dropped spoon to the floor —gravity—also operates between bodies in space. Every object in space exerts a force of attraction on every other object. When one of the objects is the moon and the other is a planet with oceans like the earth, tides result.

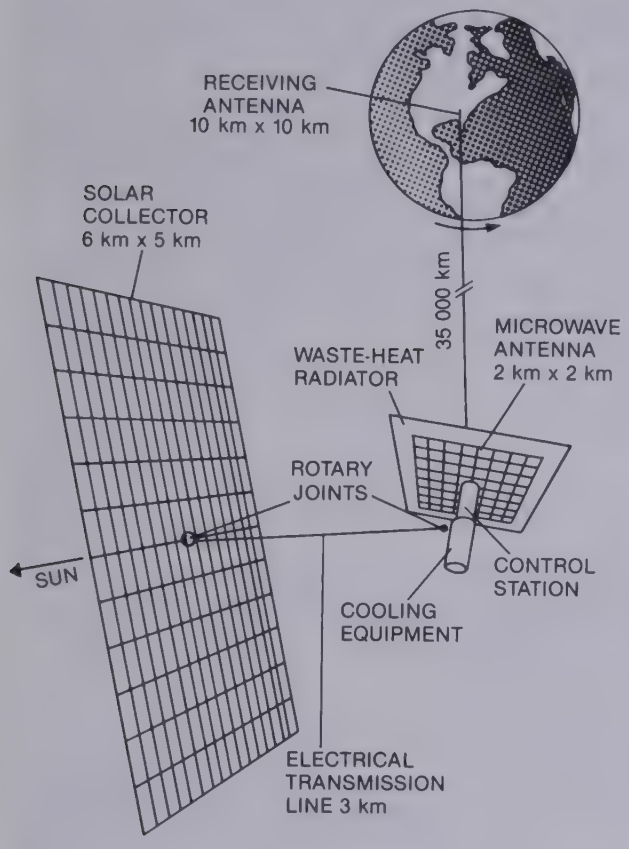
As the diagram shown here indicates, the pull of the moon is greatest on the part of earth that is closest. The result is that two low tides and two high tides can be seen along the seashore during every twenty-five hours, approximately. There are tides at the same time on inland lakes, but because lakes are much smaller than oceans the tides are hardly noticeable.

At intervals of slightly more than twelve hours the level of the Bay of Fundy rises and falls as billions of tonnes of water flow in on high tide and ebb away on low tide. The difference between the tides, on the average, is 16 m, great enough to have fascinated engineers for years with the possibility of capturing the energy in the tides. It could be done by building a dam with gates. The gates could be opened to let the water flow in at high tide, and then closed. By low tide, there would be a reservoir with water 16 m deep, enough to drive a turbine.

Since the tides are regular and inexhaustible they could be a source of useable energy. An installation in France, with a difference between high and low tides of only 8 m produces electricity. One of the main objections to such an installation is the very high cost. The latest estimate for the Fundy project is ten billion dollars, and the actual cost is likely to be more. Also, like wind, tides do not necessarily coincide with the time electricity is needed. Thus, some way of storing the electricity is needed. However, as a source of electrical energy for Nova Scotia and New Brunswick, tidal power is getting careful consideration.

1. Critics of the Fundy project claim that silt will be a big problem in the reservoir. Explain how they could be right.
2. What do you think the environmental effects of the Fundy project would be? Do research to see if you are right.

## Electricity from Solar-energy Cells

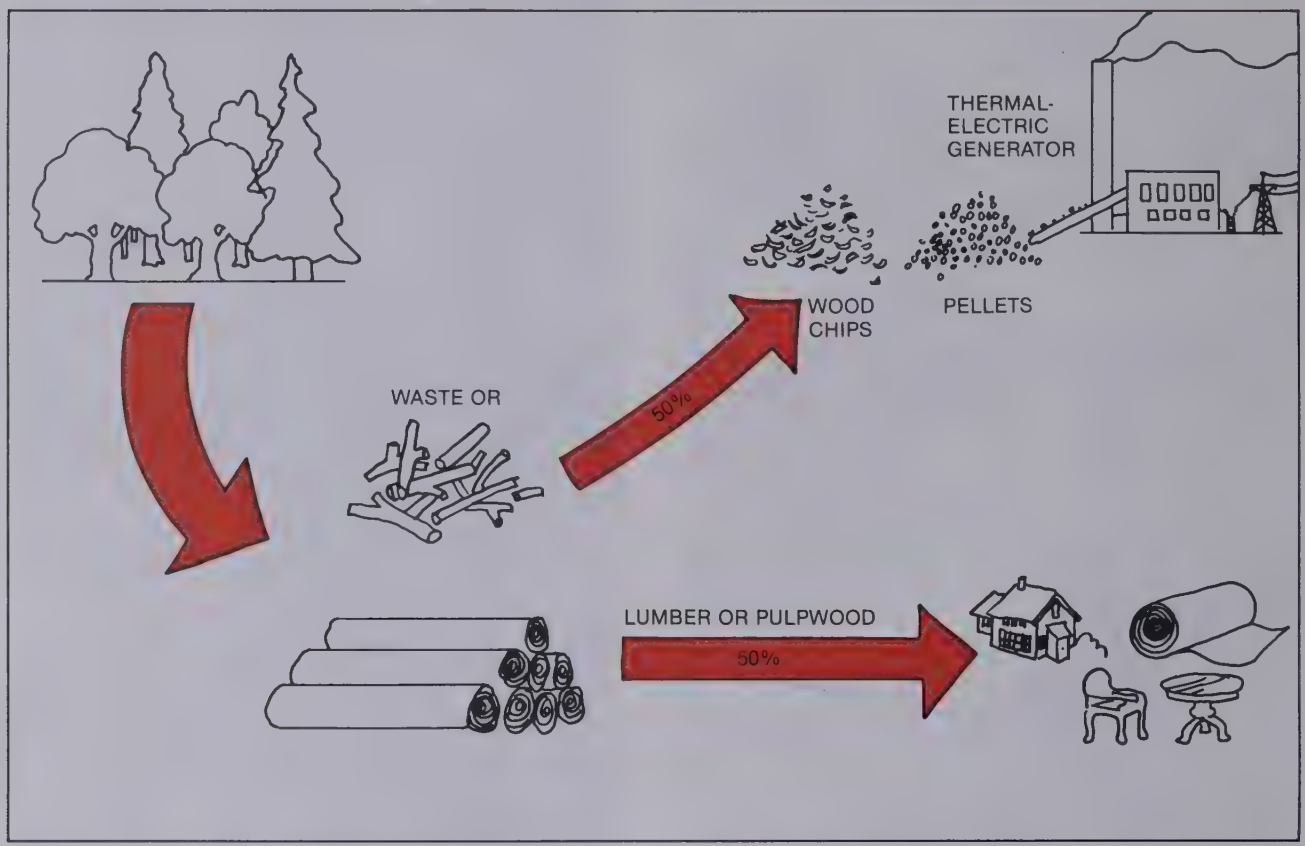


When sunlight strikes a metal plate coated with cadmium sulfide, electrons are released and a small amount of electrical energy is generated. Solar cells built on this idea are used out in space in satellites and back on earth in camera light meters. It is believed that if the cadmium plate could be made very large, electrical energy could be produced on a commercial scale. The solar collectors would be huge, say 1 km by 2.5 km. The costs of such a construction would be high, and it would have to be built in an area of continuous sunlight, few people, and low property costs.

A suggestion for the solar cell is to put it into stationary orbit above the earth. That is, the collector would be in orbit about 35 000 km from earth and would remain above the same point on earth at all times. At that distance, the cell would receive sunlight every hour of the day. The solar energy would be converted first to microwave energy and beamed to a receiver on earth, where it would be converted again into electrical energy. It is estimated that a solar collector 6 km by 5 km could produce 1 000 000 MW (megawatts) of electricity.

1. Costs for sending people and materials into space can be estimated by referring to the flights of Columbia, the NASA space shuttle. One flight costs about $25 000 000 and carries a payload of 30 000 kg. On earth, construction costs for electrical-generating stations are in the range of $1500/kW to $2000/kW. At this rate, how much money is it reasonable to spend on the 6-km-by-5-km solar cell? How many shuttle flights would you estimate would be needed to get the materials into space?
2. Collect information on microwaves. Is there any reason for concern about a powerful beam of microwaves being sent to us from space?

## Electricity from Biomass Energy




The good part of the tree as any lumber worker or wood burner will tell you is the trunk. When trees are harvested, roughly 50% of the tree is kept. The other 50%, mainly the branches and twigs, is discarded. However, all parts of the tree are stored solar energy. Some recent experiments have tried to capture and use the stored energy in the parts of the tree that are usually thrown away. The branches were ground up into wood chips and wood pellets. This waste wood was then used as fuel for a steam boiler. Many pulp-and-paper mills use wood-fired generators to make their own electricity.

When trees and plants are considered as a mass source of energy, the word *biomass* is used. About 250 ha of biomass will yield roughly 1 MW of electrical energy from a wood-fired thermal-electric plant.

Canada has about 25 000 000 ha of timberland. Some people have suggested that part of this could be harvested for energy rather than for lumber or pulpwood. However, at the current high prices for lumber and pulpwood, this would be very expensive fuel. Energy plantations are a better possibility. Low-grade land that is not suitable for crops will still grow trees. This land could be planted with fast-growing trees and harvested at regular intervals.

It must be remembered, though, that burning wood produces smoke. Wood smoke contains solid particles, sulfur oxides, carbon monoxide, hydrocarbons, and nitrous oxides. It can be a significant cause of air pollution in large quantities.

1. Could wood chips be an additional source of fuel for a chemical electric-generating plant? Could some of our trees be used for this purpose?
2. How many megawatts of electrical energy would be generated from 10% of our timber resources?
3. Is it wise to consider using 100% of our trees, rather than 10%? Explain your answer.

## Electricity from Geothermal Power

Breaks in the crust of the earth sometimes show evidence of what the earth is like far beneath our feet. Hot springs and geysers are small indicators of the tremendous heat still in the earth's core. If wells are drilled in an active area, steam can rush to the surface with enough force to drive turbines and generate electricity. This has been done in western parts of the United States, in Iceland, Italy, and New Zealand. Success naturally depends on the strength of the steam source. Usually only small-scale power generation is possible, but costs are lower than with fossil-fuel plants.

One problem with geothermal power concerns pollution. The steam that rises from deep in the earth brings strong chemicals with it. In the past, geothermal power systems have just let the hot water flow into streams. The temperature of the streams rose to dangerous levels and the chemicals polluted the water.

1. Find out where in Canada there is evidence of underlying steam beds.
2. How is geothermal energy used in other parts of the world? Do research to find out.

## Electricity from Small-scale Hydro

Most of the hydroelectric projects under construction these days are very large. The James Bay installation in Quebec, for example, will eventually have a reservoir with an area twice the area of the province of Prince Edward Island. Hydroelectric plants were not always on this scale. Scattered around the country are small hydroelectric plants on small rivers that supply electricity for small local communities.

Most provinces have some suitable small-scale hydroelectric sites. Quebec is believed to have 10 000 MW of undeveloped hydroelectric resources and Ontario has more than 1000 sites that could produce a total of 12 000 MW. These numbers compare with the capacity of one thermal-electric generating station.

Small installations tend to cost more to build per kilowatt hour than large ones. But a large generating system needs large and costly distribution systems, and small systems do not. Thus, the total costs for a kilowatt hour of electrical energy may be similar for both systems.

1. Take the point of view of conservationists, campers, and fishermen. Comment on the proposal to provide electricity by small-scale hydroelectric installations on the smaller rivers of your province.
2. Take the point of view of the electric-power company. How would the construction of many small hydroelectric stations, each one owned by a different community, be viewed by the provincial power company?

# 7

# Electricity in the Future

### The Wise Use of Energy

Imagine that you have the task of deciding the future of the production of electricity in your province. Think about present needs and probable needs in the future.

Try to be a good manager. You will have to spend some money on development if you want to increase production, but remember that every dollar spent on electric-power plants cannot be used to meet other important needs, such as health care and education.

Your task is to plan a course of action for your province. The following suggestions and notes will help you.

- Your province may both buy and sell electric power. This is sometimes the convenient way for provinces to keep transmission lines short.
- Transmission lines are costly to build. An average power loss of 10% is expected on transmission lines. The maximum transmission distance is about 1000 km. After that, losses are so great that it is more practical to build another thermal-electric plant.
- As oil becomes more costly, homeowners may be urged to switch to natural gas or electricity for home heating.
- Conservation methods would probably cut the rate of increase in any province in half. Perhaps this would accomplish your goals.
- Since most provinces buy and sell electric power, you will want to consider the most likely energy plan your provincial neighbors will follow.
- Assume that the population in your province will increase at the national rate.
- Consider the way electric power is produced now and decide if you want a change for the future.
- Will renewable sources of energy play a part in the energy future of your province?

When you have made your decisions, write an Electric Power Scenario, a description of what you see happening to the production and use of electricity in your province from now to the year 2000. Any plan you make is certain to have some advantages and some disadvantages. Include a list of each in your Scenario.

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# Vocabulary

**A**
appliance
armature
atom
attract

**B**
blackout
boiler
bottom ash
brownout

**C**
Calorie
carbon dioxide
ceramic
chain reaction
circuit
condenser
conductor
consumer
converter

**D**
deuterium
diversion channel

**E**
electromagnetic radiation
electron

**F**
fission
fly ash
friction

**G**
galvanometer
generating station
generator

**I**
insulator
inversion
irrigation

**J**
joule

**K**
kilowatt
kilowatt hour

**M**
magnetic poles
magnetism
meter

**N**
neutron
nitrogen
nucleus

**P**
particulates
penstock
perpetual motion
plutonium
power
precipitation
proton
pulverized

**R**
reactor
repel
reservoir
resistance
revolves
runoff

**S**
smog
spillway
static electricity
sulfur dioxide

**T**
thermal-electric plant
transmission corridor
turbine

**W**
waterwheel
watt

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